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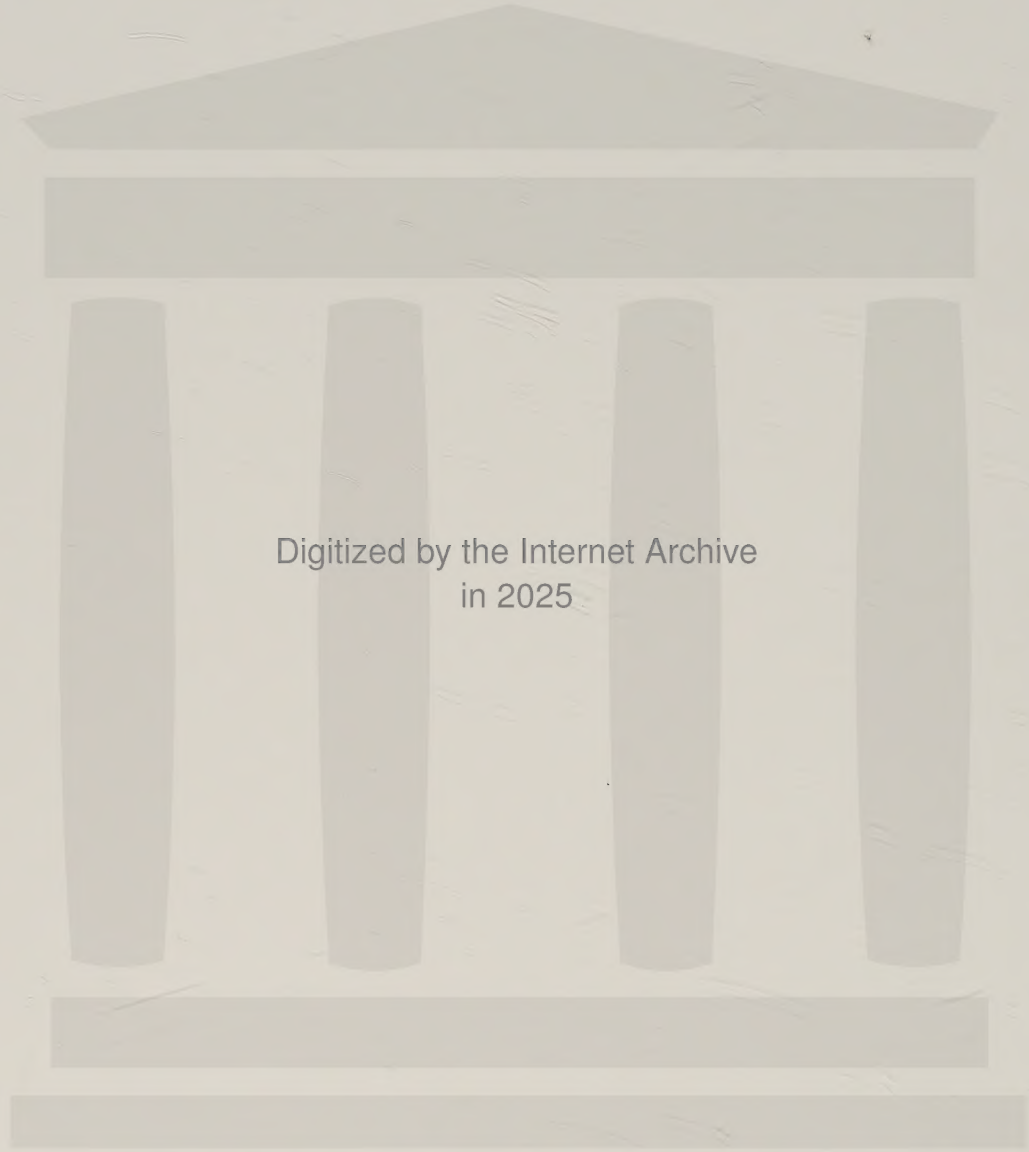

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REVIEW OF THE STATE OF WORLD AQUACULTURE

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by

Inland Water Resources and Aquaculture Service
Fishery Resources Division
Fisheries Department

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 1997

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PREPARATION OF THIS DOCUMENT

The state of the world's fish stocks and aquaculture are reviewed by the Fishery Resources Division every two years for FAO's Committee on Fisheries (COFI). The review formerly included all capture fisheries, but for the Twentieth Session of COFI it was separated into two parts: the world's marine resources, and inland fisheries and aquaculture, identified respectively as Part 1 and Part 2 of the *FAO Fisheries Circular* No. 710. Due to the increased importance of aquaculture production, the review was produced in three parts for the Twenty-first Session of COFI, March 1995, each part as a separate document under the same title: "Review of the State of World Fishery Resources". The document dealing with aquaculture was issued in 1995 as *FAO Fisheries Circular* No. 886.

This Circular updates the information provided in *FAO Fisheries Circular* No. 886, Review of the State of World Fishery Resources: Aquaculture, published in 1995. It is intended that the Review of the State of World Aquaculture will be completely revised every six years, with updates provided biennially.

The various sections of this review have been produced by the authors indicated in the Table of Contents. Z. Shehadeh was responsible for the general co-ordination and final editing of this document, with the valuable assistance of Mr. J. Maclean. Some authors also co-ordinated parts of the review which consisted of contributions from two or more authors: M. Pedini (Regional Reviews: Africa); A.G. Tacon (Regional Reviews: Asia); Z. Shehadeh and D. Bartley (Development Trends in Selected Areas). Illustrations and tables were prepared by the authors.

FAO Inland Water Resources and Aquaculture Service, Fishery Resources Division.
Review of the state of world aquaculture.
FAO Fisheries Circular. No. 886, Rev.1. Rome, FAO. 1997. 163p.

ABSTRACT

This paper updates the regular review of world aquaculture, based mainly on national statistics provided to FAO by its Members through 1995. The review is prepared in three parts. The first provides a global perspective of production and production trends, and the contribution of the sector to food fish supplies. It identifies some of the major strategic issues facing aquaculture development and presents a rough estimation of production by the year 2000. The second part reviews developments and trends in some important fields, including environmental interactions, biodiversity and genetics, feed resources, fish health and quarantine, regulatory frameworks, product safety, international trade, and international aid to research and development. The third part reviews production and production trends, as well as main development issues and outlook on a regional basis, for each of seven regions: Asia, Africa, Europe, Former USSR Area, North America, Latin America and the Caribbean, and Oceania.

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INTRODUCTION

This document updates the regular FAO review of world aquaculture production, which was issued separately from the review of inland fisheries for the first time in 1995 as FAO Fisheries Circular 886, entitled "Review of the State of World Fishery Resources: Aquaculture". Since the subject matter of the circular does not deal with the state of a natural fishery resources, it has been renamed "Review of the State of World Aquaculture".

Data on production volume (in metric tons, mt, rounded to the nearest thousand mt) and value (in current US$ for the year) are derived exclusively from the most recent FAO Aquaculture Production Statistics, FAO Fisheries Circular No. 815, Revision 9, 1997, consisting of statistics provided to FAO by reporting countries. The circular also draws upon and cites information from other FAO publications, unpublished FAO information and non-FAO information from conference proceedings, journals and books. Production and trends are covered for the period 1984-1995, in order to incorporate amendments to past statistics submitted to FAO by reporting countries. However, attempts have been made to concentrate on the more recent developments.

Some improvements have been made in the statistical data base since the first publication of this circular in 1995. The returns from several countries have arrived earlier by the use of electronic media and the quality of reports from some countries has greatly improved. The complete separation of the aquaculture and capture fisheries components of the data base has also been completed for 1984-1995, and work is in progress to extend this separation back to 1950. In addition, guidelines for the collection of quantitative structural data on aquaculture have been prepared as a supplement to the " FAO World Census of Agriculture Programme". However, many of the limitations discussed earlier (see Fisheries Circular 886, Annex 1, 1995) remain and their resolution is the subject of ongoing efforts.

This review is prepared in three parts. The first provides a global perspective of production and production trends, and the contribution of the sector to food fish supplies. It identifies some of the major strategic issues facing aquaculture development and presents a subjective estimate of production by the year 2000. The second part reviews developments and trends in some important areas likely to affect the future course of development, including environmental interactions, biodiversity and genetics, feed resources, fish health and quarantine, regulatory frameworks, product safety, international trade and international aid to research and development. The third part reviews production and production trends, as well as main development issues and outlook on a regional basis, for each of seven regions: Asia, Africa, Europe, Former USSR Area, North America, Latin America and the Caribbean, and Oceania.

Asia, as the main producer, has been sub-divided into five sub-regions to provide for more detailed reviews: China, East Asia, Southeast Asia, South Asia and West Asia. The countries included in each region or sub-region are indicated in the relevant text section. Within the five sub-regions, China is treated separately because it accounts for about 63% of world production from aquaculture. Countries of the former USSR area have been kept together under that geographic region because the separation of aquaculture statistics of the former USSR area into individual countries, from 1984 to the present, has not yet been completed by FAO.

In view of the growing complexity of aquaculture, and the need for interdisciplinary and intersectoral efforts for its development and management, efforts were made for the first time, in the preparation of this document, to incorporate inputs from various Services of the FAO Fisheries Department and from other Departments and Services within the Organization. In some instances, professional colleagues from outside the organization, with special expertise in selected subject matter covered in this review, were invited to participate, and prepared relevant sections of this document. This is a modest beginning for what is intended to be a more concerted effort in future reviews.

1. GLOBAL OVERVIEW OF PRODUCTION AND PRODUCTION TRENDS

1.1 Status of Global Production and Production Trends

1.1.1 Trends in Global Production, 1984-1995

Rana, K.J.

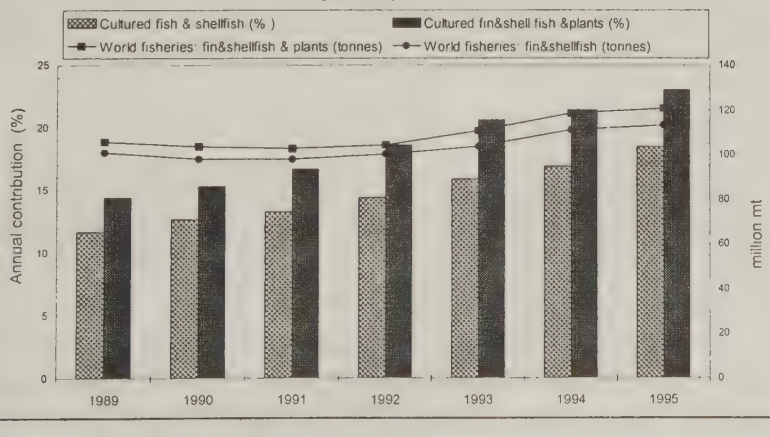
It is widely acknowledged that fish supplies from traditional marine and inland capture fisheries are unlikely to increase substantially and that the projected shortfalls in fish supply will probably be met mainly from expansion within the aquaculture sector. The growth of this sector and its potential development, as well as changes in the fisheries sector as a whole, are closely monitored by FAO, the only international agency to hold a global time-series database on capture fisheries and aquaculture.

The potential of aquaculture to meet the challenges of food security and to generate employment and foreign exchange has been clearly demonstrated by the rapid expansion of this sector, which has grown at an APR[1] of almost 10 since 1984 compared with 3 for livestock meat and 1.6 for capture fisheries production.

The contribution of aquaculture to total aquatic production

In recent years, the supply of fish has continued to increase steadily and in 1995, total world production of finfish, crustaceans and molluscs from capture fisheries and aquaculture reached 112.9 million mt. The inclusion of plants in aquatic production raises the total production in 1995 by a further 7.8 million mt to 120.7 million mt, an increase of around 15.6 million mt since 1989 (Figure 1.1.1.1).

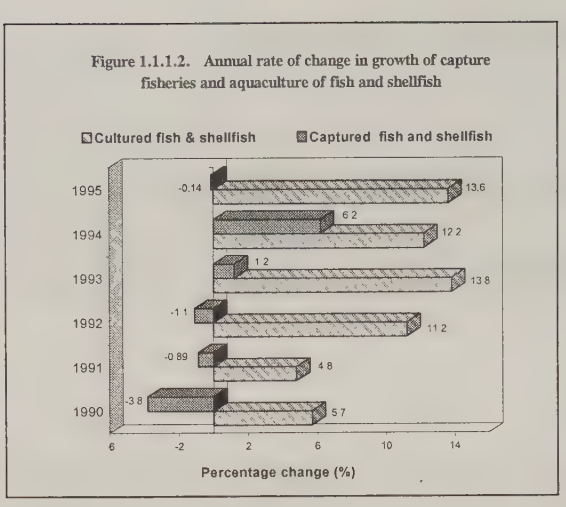
Figure 1.1.1.1. Contribution of aquaculture to annual global aquatic production

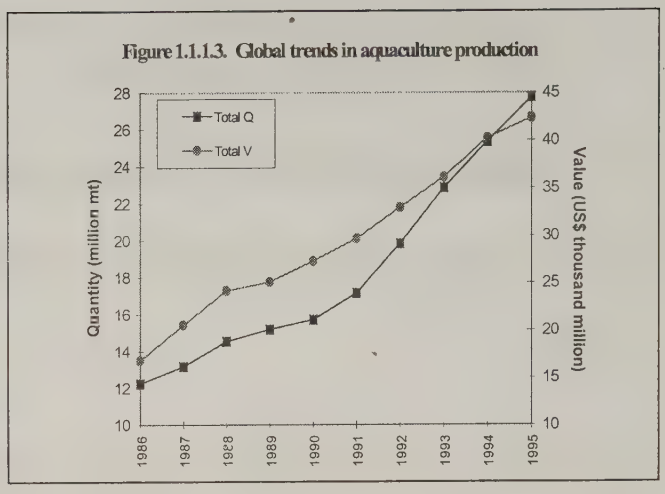


Much of the increase in annual global aquatic production is attributable to aquaculture. The actual share of aquaculture depends on whether aquatic plants are included or not (Figure 1.1.1.1). For cultured finfish and shellfish, the annual contribution to total finfish and shellfish production rose linearly from 11.7% in 1989 to 18.5% in 1995.

When aquatic plants from culture and wild harvest are included, the corresponding annual contribution of aquaculture to total aquatic production increased from to 14.4% in 1989 to

[1] Annual Percent Rate: average annual compounded growth rate in percent.





23.0% in 1995. For food fish, over a quarter of total world supply was derived from aquaculture.

The annual growth rate of cultured finfish and shellfish production over the last five years increased from an APR of around 5-6 between 1990-1991 to around 14 in 1994-1995. In contrast, with the exception of the increase in 1993-1994, which is probably attributable to small pelagic fish, data reported for capture fisheries show near zero or negative growth (Figure 1.1.1.2).

The global contribution of aquaculture

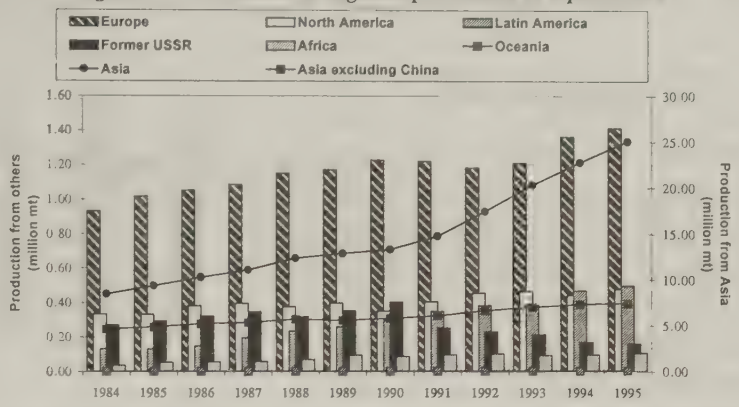
Aquaculture is one of the fastest growing food-producing sectors, providing an acceptable supplement to and substitute for wild fish and plants. By 1995, the total production of cultured finfish, shellfish and aquatic plants, which was valued at US$42.3 thousand million reached a record 27.8 million mt, an increase of around 9.6% and 5.2% over 1994 production in quantity and value, respectively (Figure 1.1.1.3). In keeping with recent trends, the increase over 1994 was highest for finfish and shellfish: 13.6% and 7.4% for quantity and value, respectively. Much of the reported increase originated from the low-income food deficit countries (LIFDCs), in particular China, and reflects the continuing trend in these countries of increased use of aquatic resources to further diversify food production.

Regional growth of aquaculture

Regional, cultural and historic attributes have played major roles in influencing both the production base and rate of expansion of aquaculture. The historic tradition of growing fish in Asia, which is well documented in countries such as China, India, Cambodia and Indonesia, has played a significant role in maintaining Asia's dominant role in aquaculture. Production of finfish, shellfish and plants from culture in Asia increased from 8.4 million mt in 1984 at an APR of 10.4 to over 25 million mt in 1995 (Figure1.1.1.4) and accounted for over 90% of world output. Much of this growth, however, specifically relates to China. When China is excluded, the growth rate (APR) of the sector in Asia is only 4.4, not too dissimilar to that in Europe (3.9) and North America (3.6). In Africa and Latin America, the aquaculture production base is considerably lower and although aquaculture traditions are uncommon, the sector has expanded at higher rates. In Africa, production increased at an APR of 12.7 from 25,000 mt in 1984 to 107,000 mt in 1995. Similarly, in Latin

America, aquaculture production has expanded at an APR of 12.8 since 1984 and in 1995 reached 500,000 mt. These varying rates of expansion have altered the contribution of regions to global aquaculture in recent years (Figure 1.1.1.5). The global share of Asia increased by 7% between 1984 and 1995. In the same period, Latin America's share increased by around 0.5% while those of Europe, Former USSR and North America decreased by 4%, 2% and 2%, respectively.

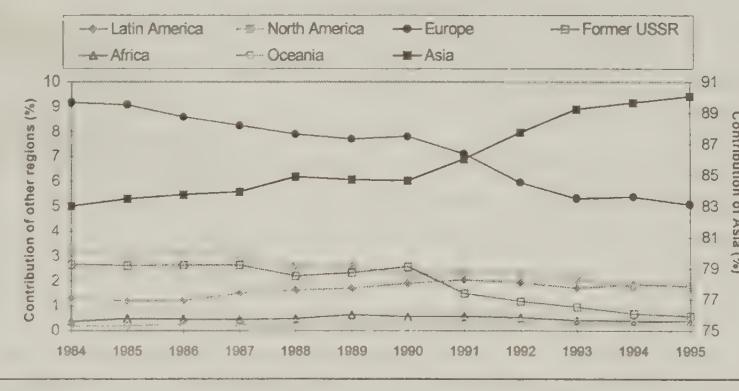
Figure 1.1.1.4. Trends in regional production of aquaculture



Contribution of aquaculture to total national aquatic production in principal countries

Although the global contribution of aquaculture by quantity to total world aquatic production averaged 23% in 1995, the relative importance of aquaculture to national aquatic production varied greatly and ranged from 7% to 60% in the top 14 producing countries (Figure 1.1.1.6). In keeping with recent trends, the significance of aquaculture in terms of contribution in tonnage to national aquatic production in 1995 was greatest in China, accounting for 60.2% of total national production, nearly twice that in France, India, Republic of Korea and the Philippines (Figure 1.1.1.6A). A considerably lower contribution of aquaculture to national aquatic production was reported by Thailand (13.2%), Norway (9.4%) and the USA (7.2%) in 1995 (Figure 1.1.1.6B).

Figure 1.1.1.5. Trends in regional contributions to global aquaculture production (%)



China, India and Japan accounted for 63.4%, 5.8% and 5.1% of total world aquaculture in 1995, respectively (Figure 1.1.1.5). Contributions by other major producers were lower, with the Republic of Korea, Philippines, Indonesia and Thailand accounting for 3.7% (1

Figure 1.1.1.6A. Contribution of aquaculture to national aquatic production (%)

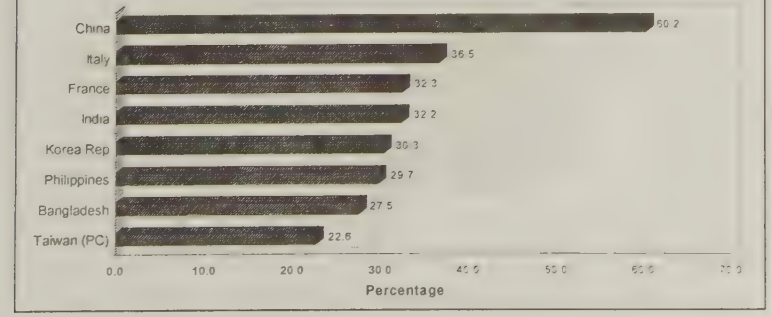
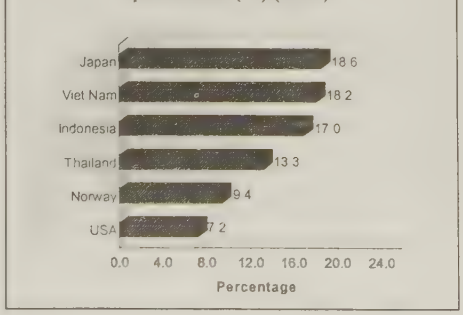
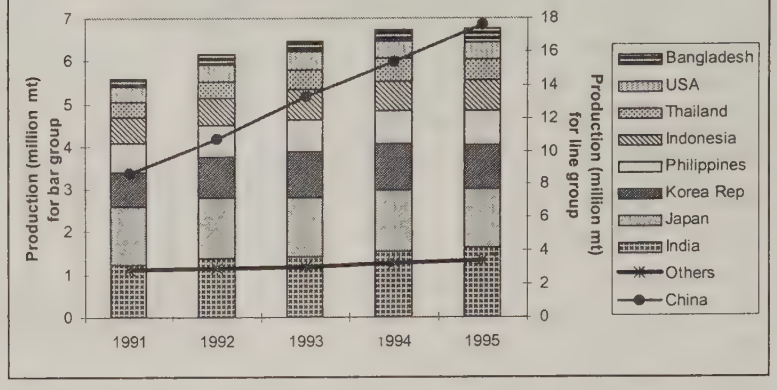


Figure 1.1.1.6B. Contribution of aquaculture to national aquatic production (%) (cont.)



million mt), 2.9% (0.8 million mt), 2.6% (0.7 million mt) and 1.7% (0.5 million mt), respectively. The ranking of some countries in 1995 has changed over the last five years (Figure 1.1.1.7). The positions of China (1st), Republic of Korea (4th), Philippines (5th), and Indonesia (6th) remained unchanged since 1991. India replaced Japan as 2nd and Thailand displaced the USA to take the 7th position in 1995. Although a few developed countries feature amongst the top producers (Figure 1.1.1.7), aquaculture is mainly an activity of the LIFDCs (Figure 1.1.1.8). By 1995, 21.6 million mt, or around 78%, of world total finfish, shellfish and aquatic plant production originated from LIFDCs. The growth rate of the aquaculture sector in LIFDCs between 1984 and 1995 was nearly six times faster than that for non-LIFDCs.

Figure 1.1.1.7. World share of total aquaculture production by major countries



Aquaculture production and growth in the 67 reporting LIFDCs, however, is greatly skewed. Around 98.5 % of all aquatic production within LIFDCs originated from just six countries in 1995, with China accounting for around 82% of production (Figure 1.1.1.9). Between 1984 and 1995 Chinese aquaculture expanded at an APR of 13.6. The APR for all the other LIFDCs countries was 5. In 1995, total aquaculture production from LIFDCs excluding China was only 4.0 million mt, an increase of 1.7 million mt since 1984 (Figure 1.1.1.8). While these LIFDCs show potential for expansion, their slow aquaculture growth rate is likely to be due a combination of reasons, such as low national priority of aquaculture, limited water supply of appropriate quality, poor infrastructure, limited capacity of institutions, and technical and financial constraints.

Figure 1.1.1.8. Annual global changes in total aquaculture production, by LIFDC status

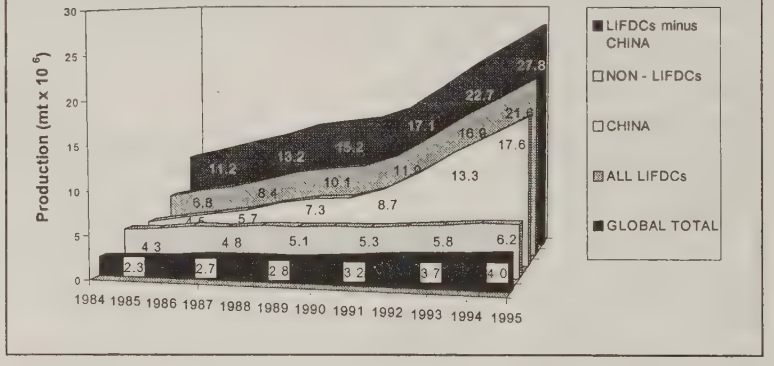
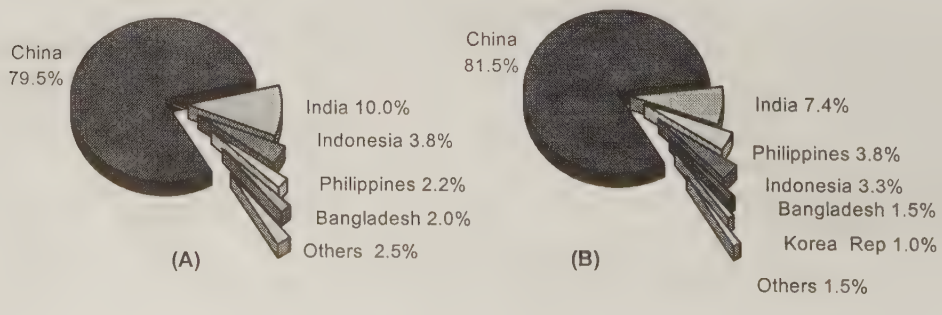


Figure 1.1.1.9. Contribution of the top 5-6 countries to total (A) finfish and shellfish and (B) finfish, shellfish and aquatic plant production in LIFDCs



1.1.2 Aquatic Environments and Use of Species Groups

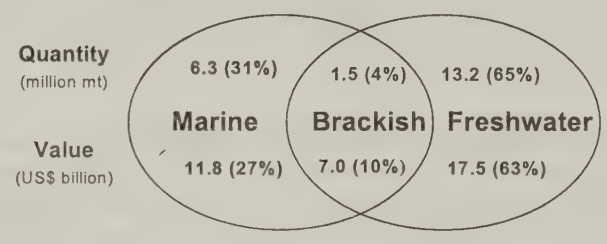
Rana, K.J.

Reported use of culture environments for aquaculture production

Although the controversy on the merits and use of coastal lands for aquaculture continues, data reported to FAO on the global pattern of environments used for culture suggest that aquaculture output from brackishwater environments has only increased by an APR[1] of 2.6 between 1990 and 1995, compared with APRs of 10.8 and 10.6 from freshwater and marine environments, respectively.

In 1995, the brackishwater environments accounted for only 5.4% and 16.6% of total aquatic production by quantity and value, respectively, compared with around 47% by quantity and 41-42% by value from freshwater and marine environments (Figure 1.1.2.1).

Figure 1.1.2.1. Contribution of key environments to global aquatic production in 1995.

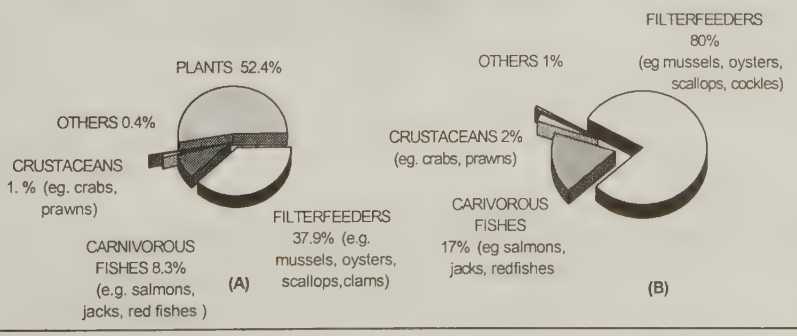


Total quantity: 27.77 million mt; Total value: US$42.32 billion

Moreover, if aquatic plants are excluded from total aquaculture production, the contribution of finfish and shellfish from freshwater environments continues to dominate output and in 1995 accounted for around 63% of the total tonnage of cultured finfish and shellfish. Culture from brackishwater and marine environments contributed 7% and 30%, respectively.

The proportion of total aquaculture production from marine waters was high (Figure 1.1.2.2). The reported data suggest that over 90% of mariculture production was aquatic plants and filter-feeding invertebrates, 8% mainly carnivorous finfish species and 1% crustaceans (Figure 1.1.2.2A). When only aquatic marine animals are considered, around 80% of the production was accounted for by filter-feeding shellfish, 17% by mainly carnivorous finfish and 2% by crustaceans (Figure 1.1.2.2B). Mariculture generated nearly US$18 thousand million in 1995; the predominant culture of aquatic plants and filter feeders contributed to reducing the nutrient enrichment of coastal waters resulting from agriculture and other human activities external to the sector.

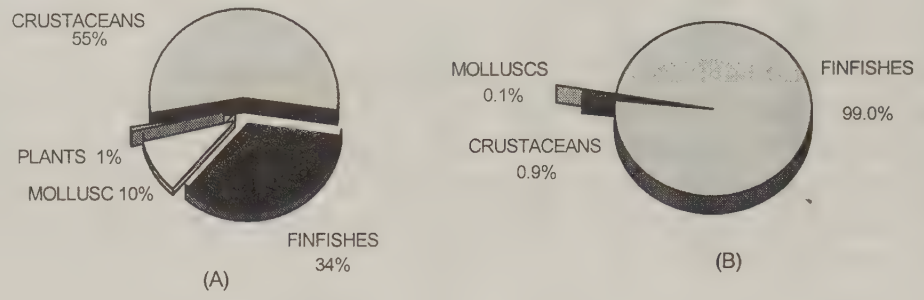
Figure 1.1.2.2. Reported use of world marine environment for (A) total aquatic and (B) finfish and mollusc production in 1995.



Brackishwaters have been used to produce a diverse range of aquatic products (Figure 1.1.2.3A). The main group are the

[1] Annual Percent Rate: average annual compounded growth rate in percent.

Figure 1.1.2.3. Global use of (A) brackishwater and (B) freshwater environments for the production of major groups of aquatic organisms



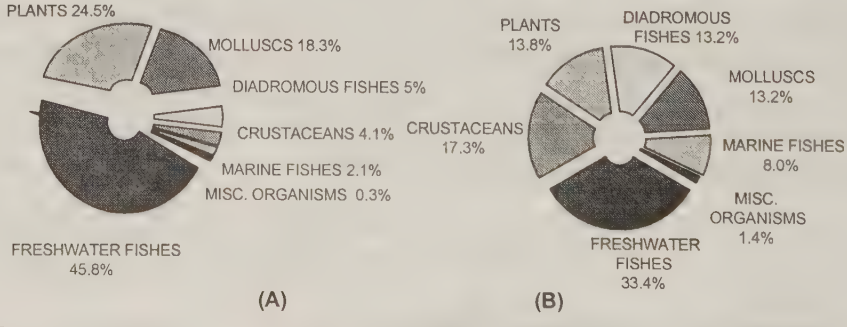
crustaceans, mostly prawns, which accounted for 55% of the production from brackishwaters in 1995, and 44% was made up of finfish such as tilapias and various diadromous fishes (e.g. milkfish), and molluscs. Freshwater bodies were used predominantly to produce finfish such as carp, catfish, tilapia and trout (Figure 1.1.2.3B).

Major cultured groups of aquatic organisms

The contributions of major culture groups in 1995 were similar to those of 1994. Production of finfish continued to be the dominant global aquaculture activity, accounting for about 53% by weight and 55% by value in 1995 (Figure 1.1.2.4).

As in previous years, freshwater finfishes, in particular the Chinese and Indian carps, accounted for the greatest share (45.6%) of total aquaculture production. Although higher in value, the diadromous and marine finfishes collectively accounted for only 7% of total weight. Aquatic plants, which were valued at nearly US$6 thousand million, contributed a quarter of total production. As in 1994, crustaceans, whilst only accounting for 4.1% of total tonnage, were the second most important cultured group in monetary terms, accounting for 17.3% of total value (Figure 1.1.2.4).

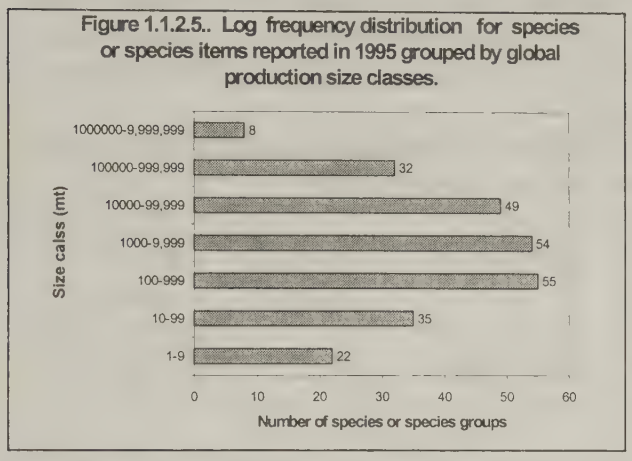
Figure 1.1.2.4. Percentage of production in (A) tonnage and (B) value of major cultured groups of aquatic organisms in 1995



Production trends in cultured species and species groups

The overall trend of increasing the number of cultured species while raising the production of more 'traditional' species continued in 1995. The rate of expansion of the latter increased in countries having appropriate technical skills and resources, although the reported production of several species and species groups was lower than in the recent past. The number of species used for aquaculture may in fact be considerably higher than reported. This is evident

from the rapidly growing and undesirable practice of reporting incompletely classified species to FAO.



Of the more than 300 cultured species or species groups that have been reported to FAO since 1984, just over 250 were reported in 1995. The contribution of each species or species group to overall production is far from uniform. In 1995, 65% of all reported species or species groups contributed less than 10,000 mt each to global production; 32 species contributed between 0.1million mt and 1 million mt and eight contributed more than 1 million mt each (Figure 1.1.2.5). The highest rate of growth and reported global production for 1995 was the kelp, *Laminaria japonica,* totalling just over 4 million mt (Table 1.1.2.1). Three of the top ten aquatic species produced were plants (Figures 1.1.2.6A and B).

Table 1.1.2.1. Reported world production of the top eight species or species groups in 1995

Common name	Species name	Production (million mt)
Kelp	*Laminaria japonica*	4.06
Silver carp	*Hypophthalmichthys molitrix*	2.56
Grass carp	*Ctenopharyngodon idellus*	2.10
Common carp	*Cyprinus carpio*	1.78
Unclassified fresh-water fishes	Osteichthyes	1.28
Bighead carp	*Aristichthys nobilis*	1.26
Yesso scallop	*Pecten yessoensis*	1.14
Pacific cupped oyster	*Crassostrea gigas*	1.00

Apart from the unknown trophic levels of the unclassified finfishes, all the above species for 1995 and those of the top 10 over the last decade are organisms low in the food chain, i.e. they are either filter feeders, herbivores/omnivores or plants (Figures 1.1.2.6A and B).

The ranking of the top eight species/groups in 1995 showed little change over the last decade and the ranking of the top four remained has unchanged over the last five years (Figures 1.1.2.6A and B).

Figure 1.1.2.6A. Global trends in production of major aquaculture species

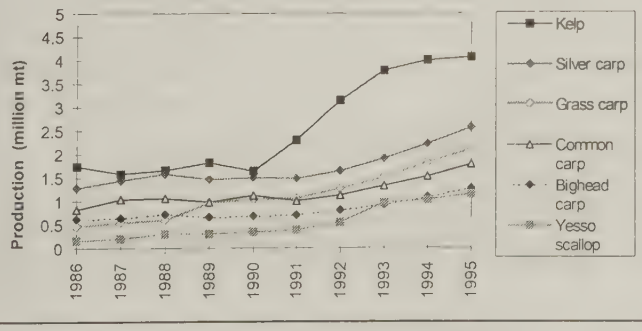
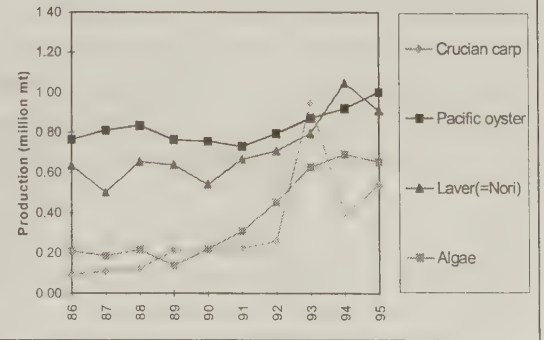


Figure 1.1.2.6B. Global trends in production of major aquaculture species (cont.)



Although highest in value, the quantity of shrimps and prawns produced does not place them amongst the top dozen or so farmed aquatic species. The major species of cultured prawn, *Penaeus monodon,* was ranked 14th in 1995; *P. vannamei* and *P. chinensis*, predominantly cultured in Ecuador and China, respectively, were ranked 39th and 42nd (Table 1.1.2.2).

Table 1.1.2.2. Production and ranking of penaeid species in 1995; ranking based on all aquatic species and species groups reported for 1995

Species	Common name	Production (mt)	% of total penaeids	Overall ranking
P. monodon	Giant tiger prawn	503,000	56.0	14
Penaeus spp. (unclassified)	Penaeus shrimps *nei*	162,000	17.4	32
P. vannamei	Whiteleg shrimp	105,000	11.3	39
P. chinensis	Fleshy prawn	79, 000	8.8	42
P. merguiensis	Banana prawn	34,000	3.8	56
P. stylirostris	Blue shrimp	10,000	1.0	89
P. indicus	Indian white prawn	2,374	0.3	126
P. japonicus	Kuruma prawn	2,240	0.2	127
Penaeid total		898,000	96.3	
Total		932,000		

A few notable major changes can be discerned between 1994 and 1995 from the data on aquaculture production collated by ISSCAAP[2] groups. These include an increase of 250% in the total production of turtles (ISSCAAP group No. 72) from 5,400 mt in 1994 to more than 19,000 mt. Similarly, the total production of sea spiders and crabs and the miscellaneous marine molluscs groups reported in 1995 increased by 97% and 196%, respectively, over that in 1994. Nearly all these increases were attributable to Chinese aquaculture. Chinese production of freshwater turtles (*Trionyx* spp.) rose from 4,400 to 17,500 mt, and the reported culture of unclassified marine crabs and unclassified marine molluscs rose from 10,000 mt to 48,000 mt and from 188,000 mt to 559,000 mt, respectively.

The overall global production of total finfish and shellfish, and carps increased between 1994 and 1995 by 13.6% and 15%, respectively. However, these increases were not uniform over time. Thailand's aquaculture output, for example, declined from 514,000 mt in 1994 to 464,000 mt in 1995, an overall decrease of 9.7%, mainly of freshwater species: an 80-90% reduction in reported production of *Cyprinus carpio* (common carp) and *Hypophthalmichthys molitrix* (silver carp), a 68% drop in *Labeo rohita* (rohu), a 40-50% decline in *Puntius gonionotus* (silver barb), *Pangasius pangasius* (pangas catfish), *Macrobrachium rosenbergii* (giant river prawn), and *Oreochromis niloticus* (Nile tilapia). These large decreases, however, were somewhat offset by an modest estimated rise of 13,000 mt (5%) in *Penaeus monodon*. Other countries reporting noticeable declines in production of finfish and shellfish in the same period included the Faeroe Islands, Japan, Netherlands, Philippines and Spain.

Opportunities for diversification and culturing new species to exploit new national and international markets were also evident from several first-time reports of species and rapid

[2] International Standard Statistical Classification of Aquatic Animals and Plants

increase in production of selected species by various countries in 1995. This was most evident in China which reported to the FAO for the first time, the production of 37,500 mt of mandarin fish (*Siniperca chuatsi*), a carnivorous freshwater perch-like fish widely distributed in Chinese reservoirs. In addition, the reported Chinese production of the river crab (*Eriocheir sinensis*) has increased 4 -5 fold in the last five years to 42,000 mt in 1995.

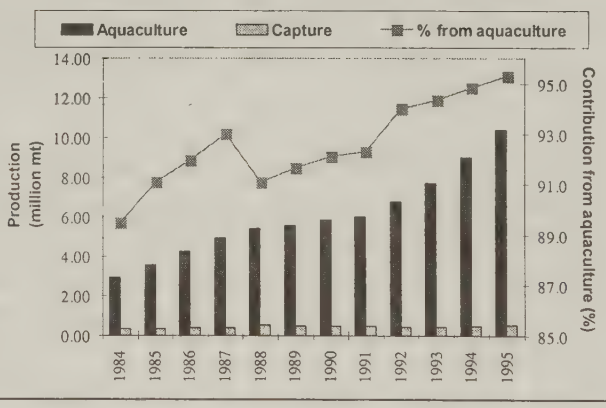
Countries in Europe also reported the production of new species in 1995. France reported 197 mt of the Japanese carpet shell (*Ruditapes philippinarum*) and Germany 1,200 mt of unclassified clams. The UK and Russian Federation reported 120 and 100 mt of Mozambique tilapia (*O. mossambicus*) and channel catfish (*Ictalurus punctatus*), respectively.

Production and main producers of major cultured aquatic species and species groups

Three finfish species groups, the carps, salmonids and tilapias, dominate finfish production and in 1995 accounted for 82% of total finfish production. For invertebrates, the major groups were mussels, oysters, scallops, clams and cockles, which accounted for 73%, and shrimps and prawns, which provided 15% of total invertebrate production. Overall, there has been a marked increase in production of both high- and low-value species. Notable features between 1984 and 1995 were that in most finfish, shellfish and plant categories, only a few species or genera dominated production, and that the growth of the subsectors was not uniform.

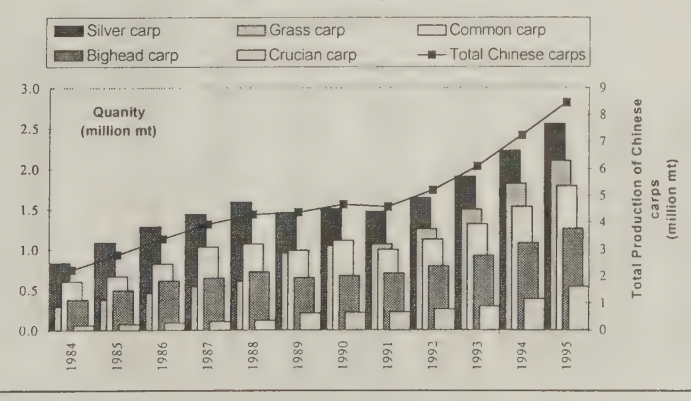
Global carp production. The total world landings of carp from fisheries (culture and capture) have increased at an APR of 11.4 since 1984, reaching 10.9 million mt in 1995; carp represent 10% of total world fishery production (including plants) and 52% of total fisheries production from inland waters. The bulk of carp landings has always been from aquaculture (Figure 1.1.2.7), which increased from 2.93 million mt or 90% in 1984 to 10.37 million mt or 95% in 1995.

Figure 1.1.2.7. Global production of carps



The carps are by far the largest group of cultured aquatic organisms. More than 26 cyprinid species and species groups have been cultured during the review period, a few of which dominate global culture: the Chinese carps (silver, grass, bighead, crucian, black and mud), common carp, and Indian major carps (rohu (=roho labeo), catla and mrigal) (Figures 1.1.2.8 and 1.1.2.9). In 1984 and 1995 these species accounted for 75% and 80% of all cultured carps, respectively.

Figure 1.1.2.8. Global production of Chinese and common carps



The culture of Chinese carp was dominated by three species, the silver, grass and bighead (Figure 1.1.2.8); in 1995 these contributed to 30%, 25% and 15%, respectively, of total Chinese carp production. Common carp made up another

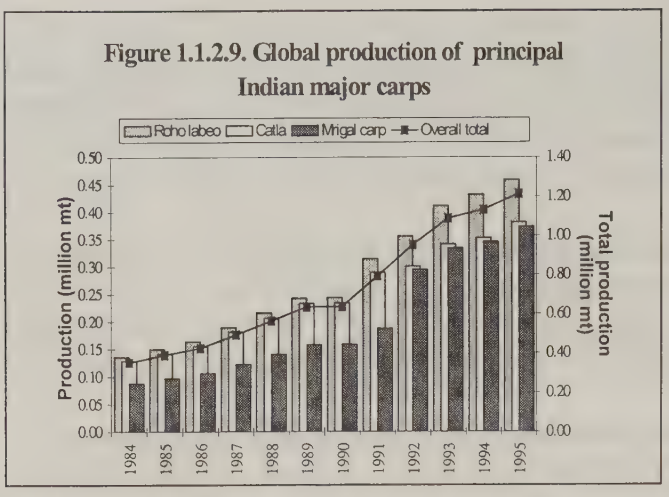


Figure 1.1.2.9. Global production of principal Indian major carps

21%. The world production of Chinese and common carps has been predominately by China: from 80% or 1.8 million mt in 1984 to 98% or 8.3 million mt in 1995. Culture of common carp is geographically the most widespread, being cultured in 86 countries. In 1995, the larger producers outside China were India (258,000 mt), Indonesia (136,000 mt), Russian Federation (33,000 mt) and Ukraine (30,000 mt).

All landings of Indian major carps were from aquaculture, and culture of three species, rohu, catla and mrigal, increased at an APR of 12 from 0.35 million mt in 1984 to 1.21 million mt in 1995 (Figure 1.1.2.9). For all three species, production between 1984 and 1990 expanded at an APR of 10. During the following five years, only the production of rohu and mrigal accelerated--with APRs of 13.5 and 18.6, respectively.

Almost all Indian major carp production has come from India, but in recent years a growing, albeit small proportion, is cultured in Myanmar, Thailand and Laos. Rohu is the most widely cultured species outside India and Myanmar is the largest non-Indian producer. In 1995, Myanmar, Thailand and Laos produced 74,000 mt, 950 mt and 1,800 mt, respectively.

Global production of shrimps and prawns

The total fisheries landings of shrimp and prawns increased at an APR of only 4.6 during 1984-1995. In common with other principal groups, this increase was predominantly due to culture. The cultured shrimp and prawn subsector grew at an APR of 16.8 between 1984 and 1995 compared with only 2.6 from capture. The contribution of cultured shrimp and prawns to total landings increased from 9% or 170,000 mt in 1984 to 29% or 932,000 mt in 1995 (Figure 1.1.2.10). There has been a plateauing of production since 1991. When only the corresponding species from capture and culture are considered, however, the contribution from culture is considerably higher. Collectively, the contribution of the giant tiger prawn,

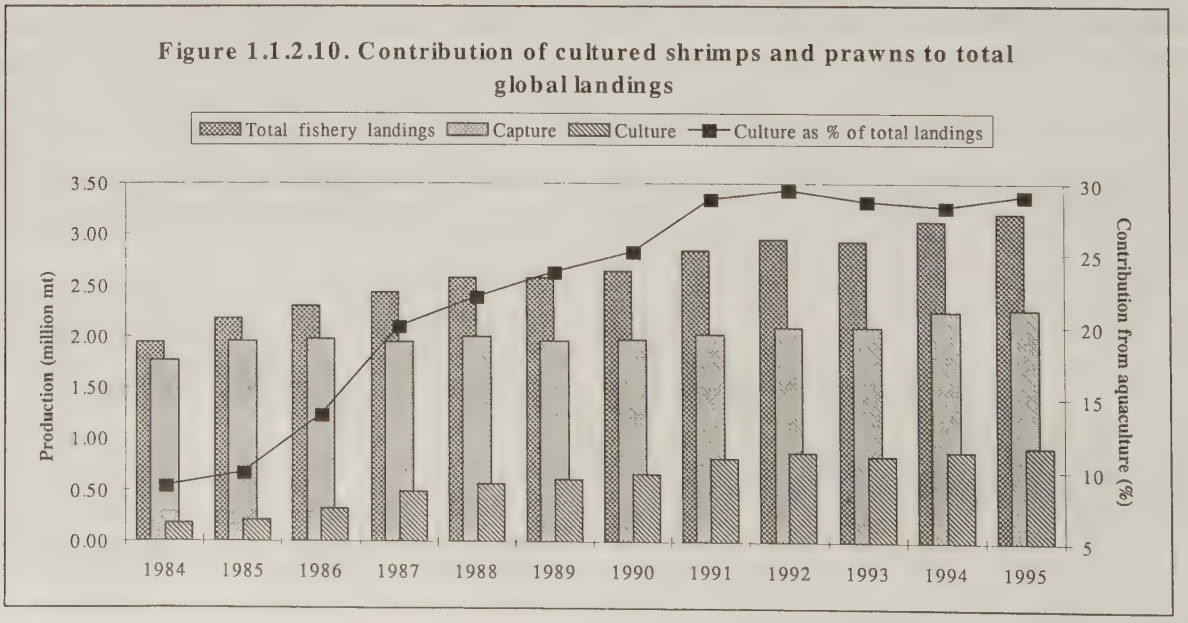


Figure 1.1.2.10. Contribution of cultured shrimps and prawns to total global landings

Penaeus shrimps *nei*[3], whiteleg shrimp, fleshy prawn and banana prawn from culture to total landing of these species/groups increased from 29.4% in 1984 to 65.2% in 1995.

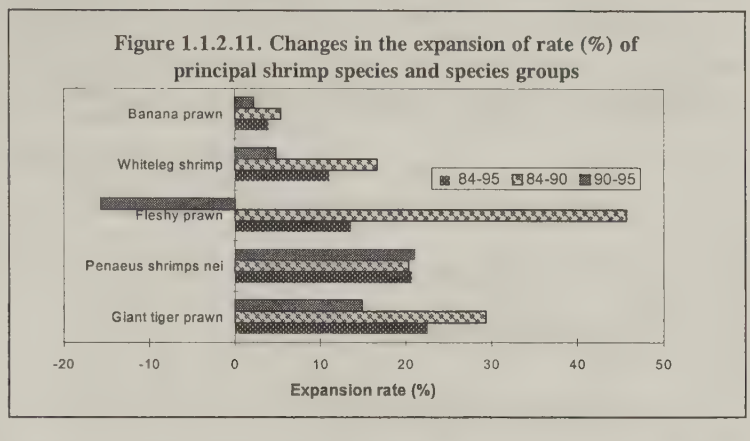


Figure 1.1.2.11. Changes in the expansion of rate (%) of principal shrimp species and species groups

The increase in contributions from shrimp farming was principally due to the culture of penaeid species, which in 1995 accounted for 96.3% of all cultured shrimp and prawns (Table 1.1.2.2). Penaeid production, notably of giant tiger prawn and unclassified *Penaeus* species, increased from 31% or 54,000 mt and 12% or 21,000 mt in 1984, respectively, to 54% or 503,000t and 18% or 165,000t in 1995. Although the production of most other major species increased in tonnage, their percentage contribution to total culture has declined since 1984 due to both their lower production base and relatively slower rates of expansion. However, the production of the fleshy prawn, 99.5% of which was produced in China in 1995, has decreased substantially in terms of tonnage since 1993; between 1990 and 1995 production decreased at an APR of -15.7 compared with a rapid APR of 45.7 between 1984 and 1990 (Figure 1.1.2.11). A decrease in the expansion rate during 1990-1995, reflecting lower production output due to environmental degradation and farming mismanagement and the subsequent disease loses during this period, was evident at the global level for each of the top five *Penaeid* species and species groups (Figure 1.1.2.11). For the giant tiger prawn, which accounted for 54% of culture in 1995, the average annual expansion rate during 1990-1995 decreased by 7.6%.

In 1995, 87% or 720,000 mt of the major cultured shrimp and prawn species and species groups originated in Asia. (Figure 1.1.2.12). Thailand was the world's largest producer, accounting for more than 55% or 277,000 mt of giant tiger prawns and 5% or 1,800 mt of banana prawns in 1995. The cultured species varied between the major producers. In contrast to Thailand, Philippines and Indonesia, China reported only the production of the fleshy prawn (78,000 mt), whereas *Penaeus* species were reported in India (10,000 mt), Bangladesh (34,000 mt) and Mexico (16,000 mt). Latin American countries cultured the whiteleg prawn --Ecuador (81,000 mt) and Colombia (8,000 mt) (Figure 1.1.2.12).

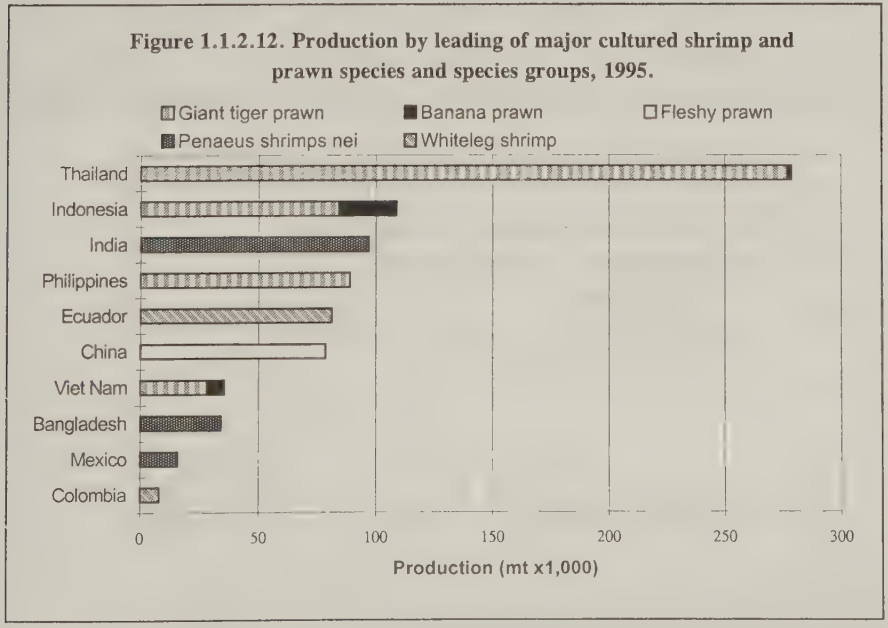


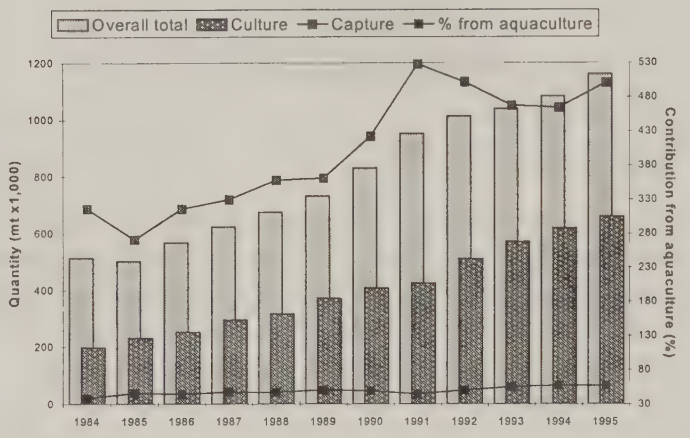
Figure 1.1.2.12. Production by leading of major cultured shrimp and prawn species and species groups, 1995.

[3] not elsewhere included

Global tilapia production

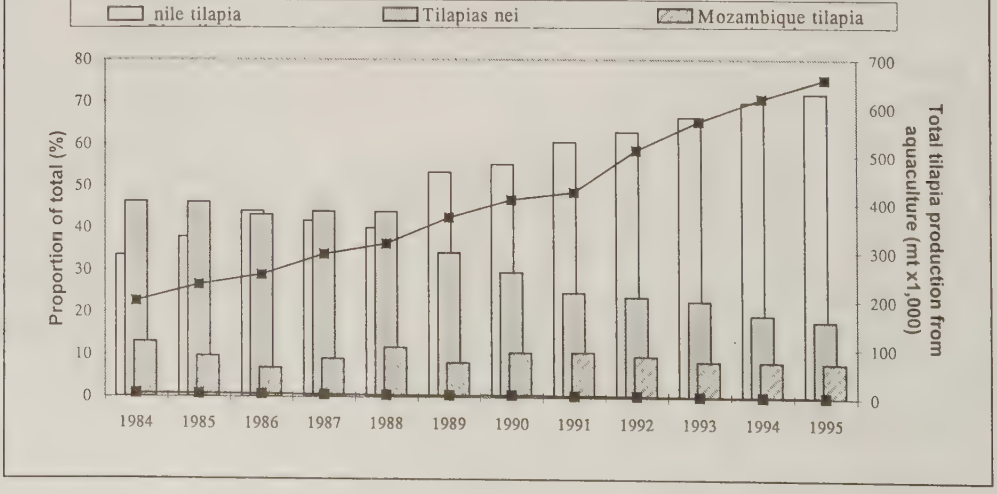
The total world landings for tilapia from capture and culture increased from 515,000 mt in 1984 at APR of 7.7, to 1.16 million mt in 1995 (Figure 1.1.2.13). In recent years, this increase in total landings has been fueled by an expansion of aquaculture. Between 1984 and 1995, the contribution of cultured tilapia to total tilapia landing increased from 38% or 198,000 mt to 57% or 659,000 mt (Figure 1.1.2.13).

Figure 1.1.2.13. Global production of tilapias



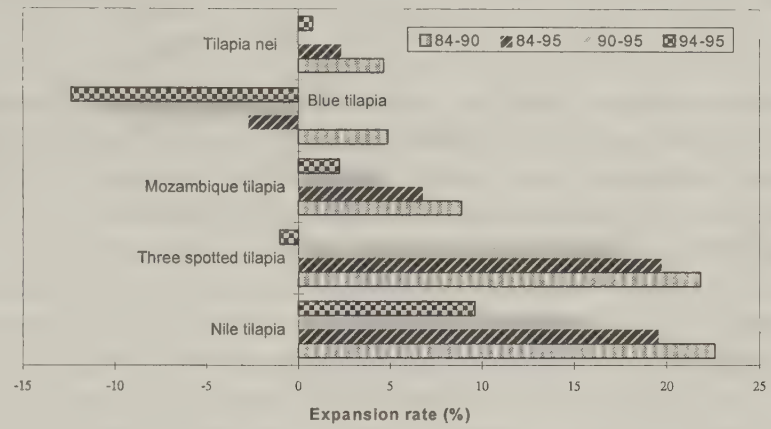
Four cichlid species or species groups (Nile tilapia, unidentified tilapias, Mozambique tilapia and blue tilapia) dominated production between 1984 and 1995; in 1995, these accounted for 99.5% of cichlid production. Global production was greatly influenced by rapid expansion of Nile and Mozambique tilapia culture in China, the Philippines, Thailand, Indonesia and Egypt. Nile tilapia dominated global tilapia culture and its share of total tilapia production increased dramatically from 33% or 66,000 mt in 1984 to 72% or 474,000 mt in 1995 (Figure 1.1.2.14). In China, the leading producer, production increased from 18,000t in 1984 to 315,000t in 1995. This resulted in China accounting for 48% of total global tilapia culture. The tonnage of incompletely identified tilapia species (tilapia *nei*) has not changed significantly, but the concurrent expansion of Nile tilapia has resulted in their global decline from 46% or 92,000 mt in 1984 to 18% or 118,000 mt in 1995 (Figure 1.1.2.14). Much of the production in this group in 1995 was attributable to Taiwan Province of China (39%), Philippines (16%), Mexico (13%), and USA (5.8%) where tilapia hybrids of species such as *O. niloticus, O. aureus, O. mossambicus, O. hornorum* and varieties known as red tilapia, cherry snapper, etc. are cultured.

Figure 1.1.2.14. Contribution (%) of major cultured tilapia species and species groups to global tilapia production from aquaculture



In common with other major cultured groups, the expansion of tilapia culture between 1984 and 1995 has not been uniform (Figure 1.1.2.15). For all tilapias, the fastest expansion was recorded during 1984-1990; thereafter, the average rate of expansion decreased. For the Nile tilapia, the expansion of production decreased from an APR of 22.6 during 1984-1990 to 9.6 in 1994-1995 (Figure 1.1.2.15). Similarly, for the same periods the production of the Mozambique tilapia decreased from an APR of 21.8 to 8.9. The production of the blue tilapia (*O. aureus*), which was mainly reported by Cuba, has declined sharply (Figure 1.1.2.15).

Figure 1.1.2.15. Changes in the expansion rate (%) of production for key cultured tilapia species and species groups

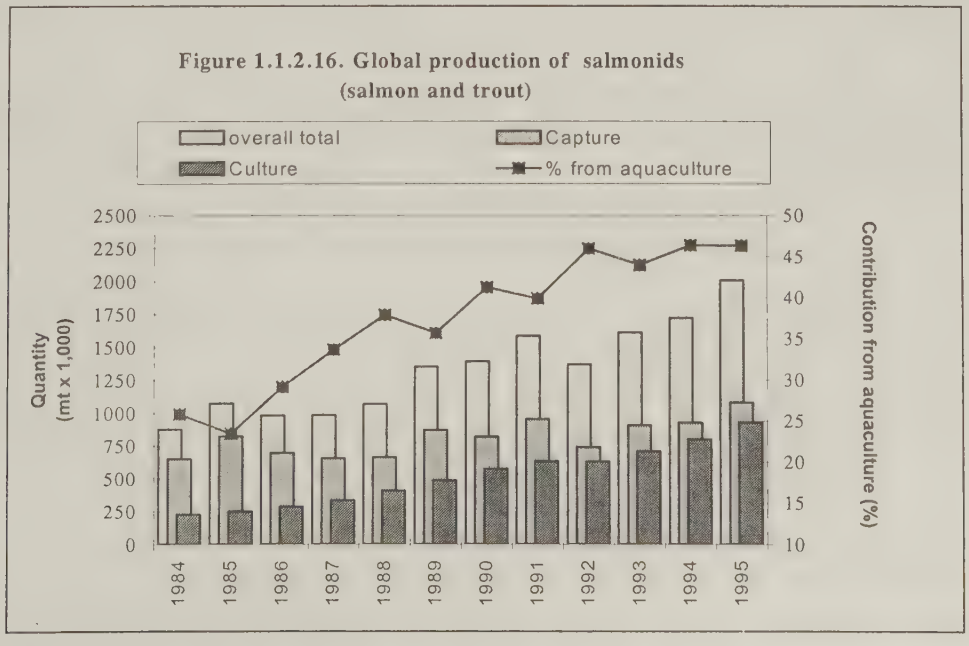


Global salmonid production

Global production of salmonids (salmon and trout) from culture and capture expanded at an APR of about 8 from 1984 to 2 million mt in 1995. A large proportion of this increase was due to the rapid expansion of cultured salmon. The share of cultured salmon species to total world salmon landings increased from 5% or 34,000 mt in 1984 to 34% or 542,000 mt in 1995. This, together with the growing contribution of cultured trout to total trout landings from 89% to 98% in the same period, resulted in an increase in the share of cultured salmonids to total global production from 26% in 1984 to 46% in 1995 (Figure 1.1.2.16).

The culture of salmonids has been dominated by four species; the Atlantic (50%), coho (6.2%) and chinook (1.3%) salmon and rainbow trout (39%) accounted for 97% of all cultured

Figure 1.1.2.16. Global production of salmonids (salmon and trout)



salmonids produced in 1995. Atlantic salmon remains the main species of salmon culture and the top three producers in 1995, Norway (268,000 mt), Chile (70,000 mt), and the United Kingdom (54,000 mt) accounted for 83% of world's production by culture. The culture of rainbow trout was geographically more widespread and reported by 48 countries. The top four countries, France (49,000 mt), Chile (43,000 mt), Denmark (41,000 mt) and Italy (40,000 mt) accounted for 48% of all cultured trout in 1995.

The production of rainbow trout has gradually increased at an APR of around 6.2 since 1984 to 385,000 mt in 1995. Salmonid production increased at an APR of 28 between 1984 and 1995: Atlantic salmon from 27,000 mt in 1984 at an APR of 29 to 472,000 mt in 1995; coho salmon from 6,400 mt to 58,000 mt; and chinook salmon , from just 100 mt to over 19,000 mt in 1991 before declining to 112,00 mt in 1995 (Fig. 1.1.2.17).

Most of this expansion took place between 1984-1991. During this period the production of Atlantic, coho and chinook salmon expanded at APRs of 38, 32 and 104, respectively (Figure 1.1.2.18). Although total production of most salmon species continued to rise by an APR of 7-15, during 1991-95 chinook salmon production declined at 12%/year.

Figure 1.1.2.17. Global production of key cultured salmon species

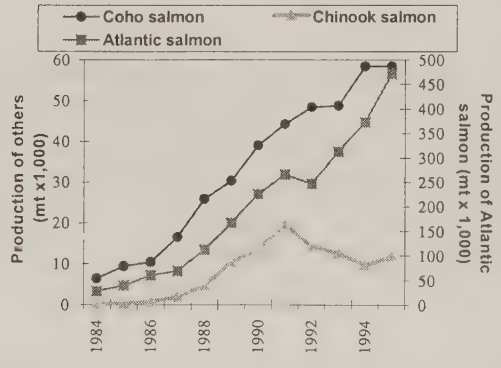
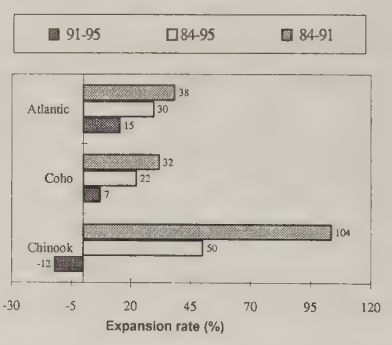


Figure 1.1.2.18. Changes in the expansion rate of culture of the main salmon species



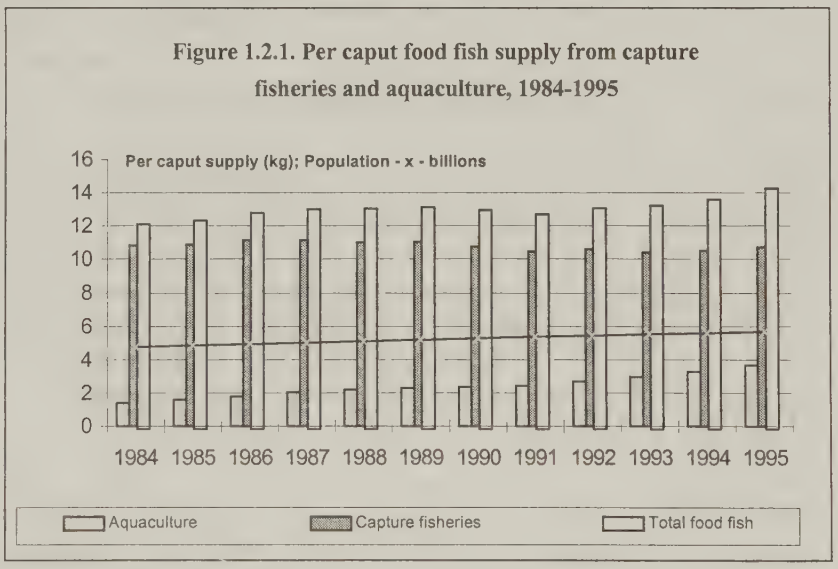
1.2 Contribution to Food Fish Supplies

Tacon, A.G.J.

Food fish supplies

Although the total production of finfish and shellfish from capture fisheries amounted to 92 million mt in 1995, only 61 million mt (live weight) or 66.3% was available for direct human consumption as `food fish'. The remainder (31 million mt) was reduced into fishmeal and fish oil for use in animal feeding or for industrial purposes. Total food fish production from capture fisheries grew at an APR of 1.5 between 1984 and 1995 (equivalent to the growth of the human population over the same period (Figure 1.2.1). By contrast, aquaculture has been the world's fastest growing food production system with food fish production increasing from 6.7 million mt to 20.9 million mt over the same period. The sector has grown at an APR of 10.9 since 1984, compared with 3.1 for terrestrial livestock meat production. The fastest growing livestock sector over the same period was chicken meat production with an APR of 5.3, followed by pig meat 3.4, mutton and lamb 1.4, and beef and veal 0.9 (Figure 1.2.2). Aquaculture's contribution toward total world food fish landings has increased more than two fold since 1984 from 11.5% to 25.6% by weight in 1995. Total food fish landings in 1995 (capture and culture were 81.9 million mt, with aquaculture contributing 23% of total finfish production (70% of total freshwater finfish, 37% of total diadromous finfish, and 1.3% of total marine finfish), 18% of total crustacean production, and 46% of total mollusc production.

Figure 1.2.1. Per caput food fish supply from capture fisheries and aquaculture, 1984-1995

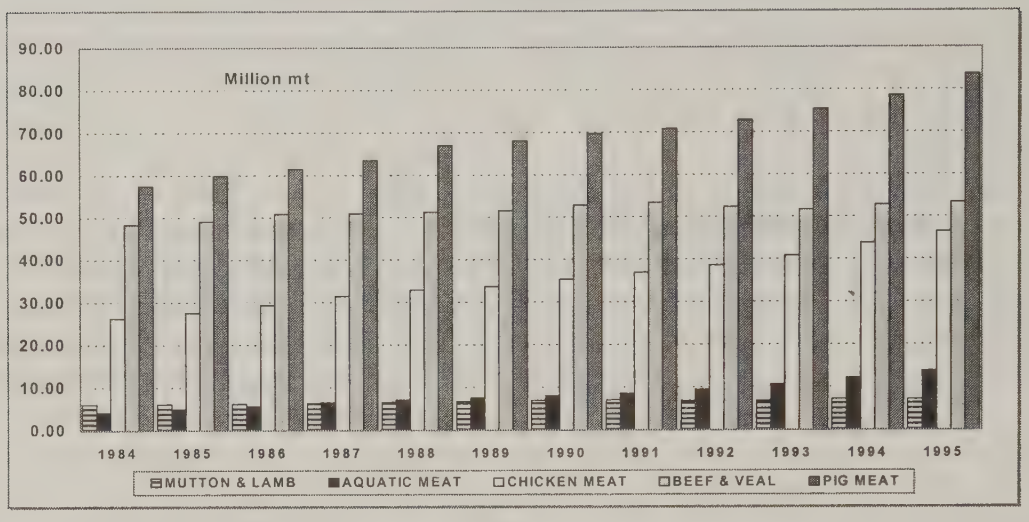


In terms of food supply, aquaculture produced the equivalent of 13.7 million mt of aquatic animal meat products (after gutting/shelling) for direct human consumption in 1995, or 6.2% of the total world farmed animal meat production of 222.1 million mt carcass weight (other products are: pig meat 37.6%, beef and veal 24.0%, chicken meat 20.9%, mutton and lamb 3.2%, all others 8.1%), thus ranking fourth in terms of global meat production.

Per caput food fish supply from aquaculture increased by 163% since 1984 from 1.40 kg (live weight) to 3.68 kg in 1995, at an average APR of 9.2. By contrast, per caput food fish supply from capture fisheries has remained relatively static: 10.8 kg in 1984 and 10.7 kg in 1995. One in four food fish consumed by humans in 1995, from a total average food fish supply of 14.4 kg, was supplied by aquaculture (Figure 1.2.3).

Of special importance is the fact that over 85% of total aquaculture food fish production came from developing countries (compared with 51% in terrestrial animal meat production), and in particular from LIFDCs, which supplied over 76% of total food fish output from aquaculture

Figure. 1.2.2 Global farmed terrestrial and aquatic meat production, 1984-1995



(as compared with only 37% in the case of terrestrial meat production). Per caput aquaculture food fish production increased nearly four fold from 1.2 to 4.5 kg between 1984 and 1995, at an APR of 12.3 (compared with a population growth rate of 2.1% in LIFDCs over the same period). Moreover, it is most likely that the contribution of aquaculture to rural food security in developing countries is greater than reported in country statistics, because household consumption by small producers is usually not recorded.

China stands out among the top ten aquaculture food fish producers in 1995, in that it produced over 61% of total world food fish production from aquaculture (12.8 million mt), with per caput aquaculture food fish production increasing five fold from 2.1 kg to 10.5 kg between 1984 and 1995 at an APR of 15.9. Moreover, China produced about 8.7 million mt of farmed aquatic meat (fish and shellfish after gutting and shelling) for direct human consumption in 1995 compared with 54.2 million mt for total farmed livestock meat production, with farmed aquatic meat ranking only second to pig meat in terms of production (Figure 1.2.4). Production of farmed aquatic meat in China increased at an APR of 16.4, compared with 10.4 for total terrestrial meat production (22.5 for beef and veal, 16.2 for chicken meat, 8.6 for pig meat, and 12.2 for mutton and lamb). Among the top aquaculture producers in 1995 (86% and 94% of total world food fish production was produced by the top 10 and 20 countries, respectively), the highest aquaculture producer of food fish on a per caput basis was Norway, at 65 kg (Figure 1.2.5).

Figure 1.2.3. Total finfish and shellfish landings from capture fisheries and aquaculture, and disposition of catch

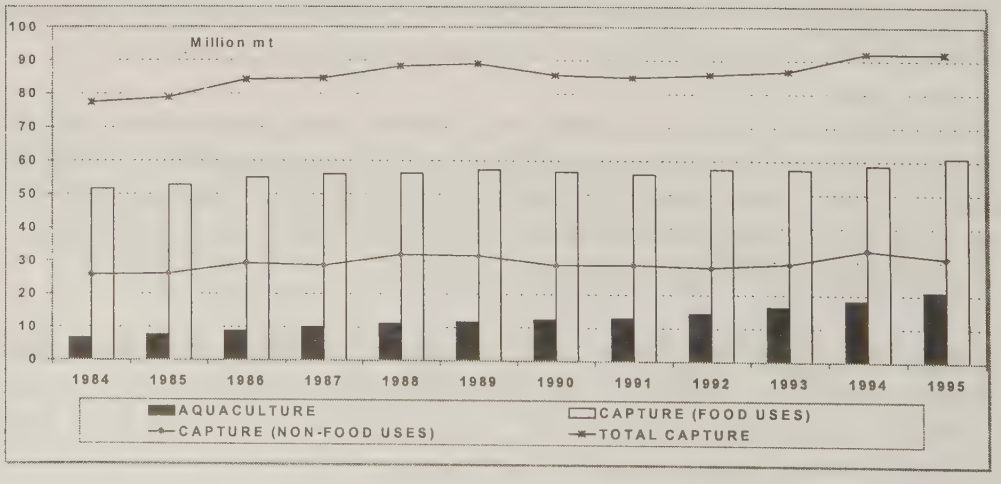
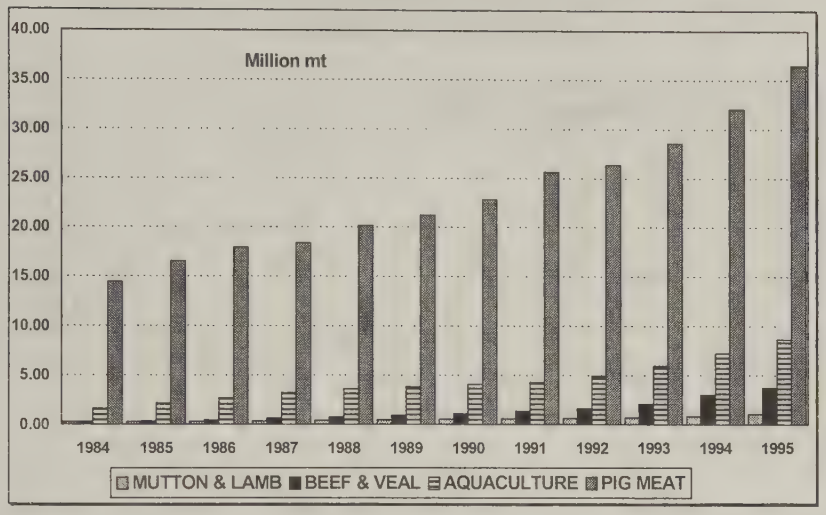


Figure 1.2.4. Terrestrial and aquatic farmed animal meat production in mainland China, 1984 - 1995



It is also important to mention here that the bulk of farmed aquatic plant production (i.e. 6.81 million mt in 1995 or 87.1% of total global aquatic plant landings, including brown, red and green seaweeds) was produced as a food source for direct human consumption (in China, Japan, Republic of Korea and Democratic People's Republic of Korea), with only a relatively minor proportion being processed as a source of carrageenans and alginates for the food industry (Xia and Abbott, 1987; Notoya, 1995; McHugh, 1996) .

Protein supply

The latest data concerning the contribution of fish and fishery products to protein supply are for 1993; they clearly show the critical role played by food fish, and in particular aquaculture food fish, in the human diet in the different regions of the world (Table 1.2.1). In 1993, aquaculture contributed more than 30% and 36% of the total food fish supply in Asia and in LIFDCs, respectively. Moreover, in most leading aquaculture-producing countries in Asia (with the notable exception of China), food fish plays a major role in human protein nutrition by supplying over one-third of the total animal protein intake [Viet Nam, 35.0% of total animal proteins; Cambodia, 38.6%; Thailand, 41.1%; Bangladesh, 46.7%; Korea Rep., 46.8%; Japan, 47.0%; Myanmar, 47.6%; Philippines, 51.5%; Sri Lanka, 51.5%; Indonesia, 53.5%; and Korea DPR, 65.2% (Laureti, 1996)]. Food fish play such an important dietary role in these countries because of their ready availability and, more importantly, affordability (lower cost than most other animal protein sources). By contrast, the bulk of aquaculture food fish production in developed countries is generally restricted to the production of higher-value (in marketing terms) food fish species for luxury or export markets. However, even in the latter case, and in the long term, aquaculture has invariably reduced the price of high-value fish and shrimp and brought them within the reach of a larger proportion of the population.

In Africa, even though the continent has the lowest per caput food fish supply (7.0 kg; a decrease of 10% since 1984) and the lowest contribution of aquaculture to per caput supply (1.5%), food fish play an essential role in supplying much needed animal protein. Africa is only second to Asia in terms of the contribution of food fish to total animal protein supply (Table 1.2.1). Sub-Saharan countries in which food fish supplied over 30% of the total animal protein intake of the population in 1993 included Uganda (31.6%), Tanzania (32.8%), Guinea (34.9%), Angola (35.7%), Côte d'Ivoire (36.0%), Senegal (37.8%), Togo (39.7%), Malawi (44.2%), Congo (45.3%), Gambia (47.3%), Equatorial Guinea (58.2%), Ghana (58.6%), and Sierra Leone (66.4%) (Laureti, 1996). Thus, while aquaculture production in most sub-Saharan countries is still very modest, the tradition of fish consumption is there to build upon.

Table 1.2.1. Fishery food balance sheet (live weight equivalent) and contribution to animal protein supply in 1993[1/]

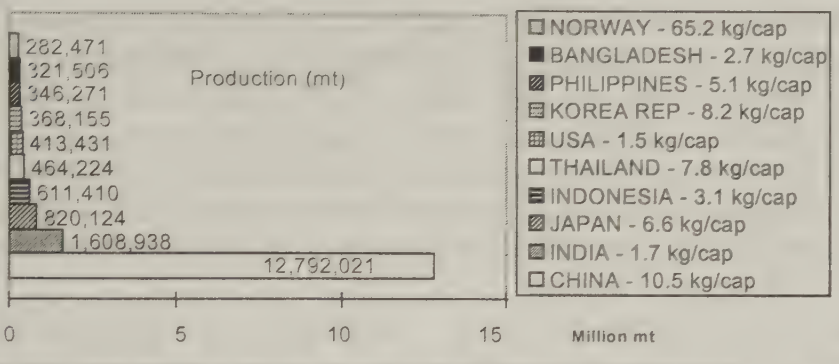
Region	Population (x 1,000)	Food fish supply (total landings, mt)	Per caput supply[2/] (total food fish, kg)	Per caput supply[3/] (aquaculture, kg)	Per caput supply (aquaculture, % total)	Fish/animal protein (%)
Africa	688,785	4,804,940	7.0	0.10	1.5	17.4
America, North	443,134	7,984,144	18.0	1.28	7.1	7.5
America, South	309,134	2,756,233	8.9	0.78	8.7	7.4
Europe	503,494	9,086,083	18.1	2.39	13.3	9.0
Former USSR	292,024	3,276,398	11.2	0.73	6.5	9.3
Oceania	27,561	552,786	20.1	2.59	12.9	8.6
Asia	3,280,094	45,559,390	13.9	4.29	30.9	25.7
China	1,175,537	16,854,300	14.3	7.55	52.6	21.5
LIFDCs	3,405,306	32,826,170	9.6	3.49	36.2	20.6
World	5,544,224	74,020,380	13.4	2.96	22.2	15.6

1/ Adapted from Laureti (1996)

2/ Total food fish production - non-food uses + imports - exports

3/ Data for aquaculture stocks and trade are not separately available. Food fish supply from aquaculture is therefore simply production divided by population.

Figure 1.2.5. Top ten aquaculture food fish producers and per caput production in 1995



If aquaculture food fish production is to contribute in a sustainable manner to food security in developing countries as a provider of an affordable source of much needed high-quality animal protein, it is essential that governments encourage the further development of aquaculture production systems targeted toward production of the lower-value herbivorous and/or omnivorous finfish and shellfish species that feed low in the aquatic food chain. These species are less demanding in terms of inputs and more efficient in terms of nutrient resource use (by avoiding the use of finite 'food-grade' animal feed inputs and maximizing the use of locally available nutrient sources and agricultural by-products; see Section 2.1 *Aquafeeds and Feeding Strategies*), as well as keeping feed and input costs to a minimum and usually within the economic grasp and capability of resource-poor farmers; thus, consumer prices are kept low (Bailey and Skladany, 1991; Tacon, 1997). For example, Cruz (in press) reported the average prices (in US$/kg) of selected fish and meat products in the Philippines in 1995 as follows: round scad ('galunggong' - wild-caught marine fish) 1.54, tilapia 2.22, milkfish 2.79, chicken (broiler, dressed) 2.78, pork (lean meat) 3.16, and beef (lean meat) 4.58. On the basis of the above, it is perhaps not surprising that Filipinos, like many other Asians, have a traditional preference for seafood, with an average per caput consumption of 40 kg/year of fishery products compared with only 16.9 kg/year for all other meats (Cruz, 1997).

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1.3 Issues and Challenges

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The aquaculture sector is comprised of a diverse set of aquatic species and farming practices, in widely varying cultural, socio-economic and institutional settings. Considering this complexity, we have attempted here to discuss only some of the broader issues facing the sector, and detail is limited. However, additional in-depth information can be accessed from the cited literature. Detailed discussion on selected topics (environment, biodiversity/genetics, feed resources, regulatory frameworks, fish health/quarantine and product safety) are also provided in Section 2, *Selected Developments and Trends*. Specific regional and sub-regional issues are presented in Section 3, *Regional Reviews*.

Sustainable development

Sustainable development is the overriding strategic issue and challenge to all economic sectors, including aquaculture. The vast majority of aquaculture practices around the world have been pursued with significant nutritional and social benefits, and generally with little or no environmental costs (FAO, 1997). However, the record is not unblemished and some forms of industrial aquaculture require further examination; actual and perceived negative impacts of aquaculture have already constrained the pace of development, mainly in the coastal zone, in some countries. In addition, many countries are looking to aquaculture to minimize the food fish supply-demand gap and to earn more foreign exchange. These countries have intensified their efforts to increase aquaculture production. This will involve the use of additional natural resources and other inputs, in a climate of increasing competition for resources and concern for the environment.

Issues of sustainability can be expected to change our perceptions of desirable forms of aquaculture development and management (Roberts and Muir, 1995); new ways of farming that strike a balance between food security and the environmental and resource costs of production will have to be adopted (Roberts and Muir, 1995; Pillay, 1996). In the future, the long-standing goal of producing particular species at competitive prices is likely to become insufficient, by itself, to realize full market potential: acceptable sustainability credentials will probably be equally essential in the future (Howarth, 1996). This trend is evident at present mainly in the case of internationally and regionally traded aquaculture products, and is manifested in initiatives to link trade to sustainability credentials (Riggs, 1996).

If aquaculture is to develop and provide for current and future needs in a sustainable manner, there is need to take stock of and address, as necessary, a number of issues, including, inter alia:

- *the establishment of an enabling environment* (e.g. strengthening of institutional capacities, decentralized management, new institutional arrangements/appropriate institutional linkages, legal and administrative framework, development policies and plans including funding, MSC, improved communications and collaboration among stakeholders, allocation of resources to aquaculture, zoning, EIA, increasing public awareness);

- *adoption of an integrated planning and management framework,* i.e. the integration of aquaculture into catchment and coastal area management as one of several sectoral users of

natural resources, and as part of managed resource systems, and into rural and agriculture development;

- *increasing the efficiency of resource use and productivity in general at the farm level* (e.g. adoption of a systems approach to management, lowering of water requirements/improved water management, better feeding strategies/less polluting feeds, genetically improved stocks, improved health management, integration with agriculture);

- *reducing externalities and avoiding irreversible damage*, i.e. negative human and environmental impacts (e.g. through consultative planning, better distribution of benefits, risk assessment, systems management, improved site selection, zoning, better engineering of farms, waste treatment and reduction, preventive health management/vaccination);

- *establishing reliable databases and effective information management systems*, as well as increasing awareness of all stakeholders and the public on the need for sustainability; and

- *maximizing positive sustainability attributes* (e.g. contribution to food security; conservation of genetic material in support of maintenance of biodiversity through stock rehabilitation and cryopreservation of gametes; reduction of pressure on key hunted stocks by provision of farmed alternatives; improvement of coastal waters through culture of molluscs and aquatic plants; small-scale integrated aquaculture-agriculture farming systems; complementing restoration efforts; contribution to pest control).

These, and many other aspects of sustainable aquaculture development have been discussed in a number of regional and international fora (e.g. ADB/NACA, 1996; FAO/NACA, 1995; FAO/Japan, 1995; Reinertsen and Haaland, 1995; Nambiar and Singh, 1996; PACON, 1995; Bagarinao and Flores, 1995).

The unanimous adoption of the Code of Conduct for Responsible Fisheries (CCRF) by the 1995 FAO Conference was a landmark in facilitating sustainable fisheries (including aquaculture) management and development. The CCRF provides, inter alia, "principles and criteria for the elaboration and implementation of national policies for responsible conservation of fisheries resources and fisheries management and development" and "standards of conduct for all persons involved in the fisheries sector" (see CCRF, Article 2 for complete list of CCRF objectives; FAO, 1995). The *FAO Technical Guidelines for Responsible Fisheries* No.5 (FAO, 1997) provides annotations to the principles of Article 9--Aquaculture Development--of the CCRF, intended to facilitate its implementation. Various other guidelines in support of the implementation of the CCRF are under preparation by FAO, and assistance is being provided to requesting countries to adapt the Code to local conditions and to develop the necessary institutional framework.

Fish farmers, entrepreneurs and government agencies do not yet have a clear idea of what the CCRF involves, how sustainability choices might apply in practice, and the economic cost of its application. The complex task at hand is to put the principles of the CCRF into operation; that is, to clarify how sustainability choices might work in practice; to incorporate its principles into development policies and plans; and to elaborate specific codes of responsible practice containing norms, standards and guidelines, agreed upon by all stakeholders. Given the diversity of aquaculture practices, and of the political, social and economic conditions in which they take place, as well as the different perceptions of "sustainability", balanced and informed approaches are required to effectively address developmental and environmental

issues at any one location (Barg et al., 1997). Further, the applicability of various approaches needs to be assessed carefully, particularly where there are many small-scale farmers involved, and in view of the often highly decentralized nature of the aquaculture industry (Phillips and Macintosh, 1996).

Finally, the capacity of developing countries to implement the recommendations of the CCRF should also be taken into account and technical assistance provided as needed (see CCRF Article 5--*Special Requirements of Developing countries*).

Many of the negative environmental effects of aquaculture can be resolved through better management at various levels, from the farm to the watershed and the shared coastal areas (Beveridge et al., 1997). In spite of the major effort needed, most of the objectives of sustainable aquaculture can be achieved through better understanding and commitment of all concerned in the development of the sector.

Institutional aspects

The importance of the wider context of development--the political, economic, social, environmental and legal factors influencing the sector--needs to be more widely recognized. In many countries, and particularly in the case of high-value species, technological advancement and the growth of aquaculture have outpaced the development of adequate planning and management frameworks. Structures of planning and development, and the legal and institutional framework in which they exist, have been increasingly challenged in responding to the emerging needs of the sector, or for creating and maintaining an appropriate climate for growth, management and control (Muir, 1995). This has sometimes led to environmental and social problems, as in the case of the shrimp and salmon culture industries.

In spite of the trend towards reduced government intervention in development, it has been argued that centralized regulations are needed to ensure equitable allocation and sustainable management of resources, especially since an integrated view of resource use, in which aquaculture is but one of several users, is essential for sustainable development and to provide opportunities for growth (Pillay, 1996; Beveridge et al., 1997; Chua, 1997). This is supported by the fact that a laissez-faire, economically driven aquaculture industry has not been sustainable on that basis alone; some measure of public intervention (monitoring and surveillance) seems to be necessary to ensure sustainability, possibly in combination with effective voluntary codes of practice. However, public consensus and participation in decision making are also essential if conflicts are to be minimized and satisfactory compromises made among competing groups (Roberts and Muir, 1995; Beveridge et al., 1997). In general, the role of public and private institutions in the regulation and support of the sector need to be worked out under prevailing local conditions and, as noted above, the practical application and enforceability of proposed approaches should be carefully assessed.

Considerable political will is a prerequisite for successful establishment of sustainable approaches to development. This involves the adoption of various policy measures which may include, inter alia, extensive consultation with and/or participation of those affected by the proposed policy measures, strict adoption of the principles of inter-generation equity, and recognition of the need to devolve management to the lowest practical level of responsibility (FAO/Japan, 1995). Difficult decisions will have to be made, often in the absence of adequate information, at almost all levels of the development process. The institutional demands are considerable. Appropriate legal frameworks, new skills and improved capacities, especially policy analysis at the sector and project levels, as well as new and efficient means of

communication, will be required. Local training is also needed to enable decentralized management. These requirements underline the need for the formation and strengthening of the appropriate institutional capacities and mechanisms for aquaculture development planning, management and control. There is also need to develop tools and guidelines and to ensure access to relevant information to help establish development policies and plans.

Resource issues

Aquaculture has requirements for land and water, and varying levels of demand for fertilizers and feeds. The characteristics of the development approaches taken will have clear implications for the extent and nature of resource use; decisions and trends in particular directions will create specific and definable changes in resource demand. Input levels and the configuration of inputs and natural resource use have significant implications for production system-environment interactions.

The increasing concern about environmental impact and general sustainability has wider resource implications. Energy analysis, ecological footprint analysis, and generalized sustainability assessments are being developed and applied to measure the resource demands and environmental cost of aquaculture, and to compare these with the potential benefits (Pimental et al., 1996; Folke and Kautsky,1989; Kautsky and Folke, 1990; Kautsky et al., 1997). Future aquaculture project assessments may involve defining not only the technical, economic and social feasibility of a project, but also its environmental efficiency. Within these broad contexts then, aquaculture, like other sectors, must compete for and justify its claims on these resources.

In many areas where aquaculture has expanded during the last decade, there is increasing pressure on the use of existing sites and there are now fewer new sites available, particularly in the coastal zone, but also inland in some countries. For land-based sites, there is increasing demand for agriculture, settlement and conservation; for water-based sites, the coastal and shore margins have an increasingly high value for settlement, recreation and conservation.

The decreasing availability of good sites and the need to overcome deficiencies of alternative, less optimal, sites will probably increase both capital and operating costs. The extent of the challenge to development will depend on the nature and magnitude of available resources, existing competition for these resources and the aquaculture development policies adopted at the national level.

Accordingly, assessments of resource use and capacity are essential for successful and sustainable aquaculture, in (a) identifying and quantifying physical, social and other factors necessary for efficient and cost-effective production, defining constraints and determining the costs/benefits of overcoming these; (b) identifying and resolving resource-allocation problems, helping to define priorities, contributing to planning processes and decisions, and providing rationales and criteria for developing resources; and (c) defining environmental limitations and providing the basis for sound and effective environmental management (Muir, 1995).

The bulk of aquaculture production is at present derived from extensive and semi-intensive production systems but there is a clear and accelerating trend towards more intensive forms of production to meet market demand for fish. One of the major questions in the development of the sector will be that of the mode of intensification, or the nature of the production systems

being developed. This has clear implications for the extent and nature of resource use and the magnitude of potential environmental externalities.

Given these demands at the strategic level, as well as that of the individual enterprise, it is clear that efforts to improve resource-use efficiency, and to conserve critical inputs, will become increasingly important (Muir, 1992; Beveridge and Phillips, 1993). This should be a priority topic for systems research. Possible benefits are illustrated by the culture of salmon in Norway, where a combination of low-pollution feeds, vaccines, genetic improvement, lower stocking densities and improved feeding strategies have increased resource-use efficiency, reduced externalities and maintained an acceptable profit margin in the face of falling market price (Blakstad, 1995). Resource-use efficiency may also be achieved through integration of aquaculture with irrigation systems and agriculture, as well as through use of inland surface waters and floodplains for certain forms of aquaculture production. Increasing the awareness of policy makers and planners in agriculture about opportunities for and economic benefits of such integration would help it become a reality. The motivation for such integration will probably increase with increasing pressure on resources. There is also need to encourage and support research to develop new forms of integrated aquaculture-agriculture systems, and other innovative systems that can effectively respond to resource and environmental challenges. In this connection, attention should be given to resolving the economic and evironmental challenges of stock enhancement and ranching, as well as of off-shore cage culture.

Information and communication

The management of aquaculture has become a complex task. The challenges associated with sustainable development demand interdisciplinary and intersectoral strategies. These will require, inter alia, access to information on a variety of topics, and to efficient tools to integrate and analyze multidisciplinary and intersectoral data. Development in the absence of reliable information, planning and management would have to proceed under conditions of high uncertainty about the impact of selected policy directions and development plans. In recognition of this, Article 9.2.4 of the CCRF urges that: "States should establish appropriate mechanisms, such as data bases and information networks to collect, share and disseminate data related to their aquaculture activities to facilitate co-operation on planning for aquaculture development at the national, regional and international level." (FAO, 1995).

Access to and effective dissemination of reliable and relevant information in a useful form is needed more urgently now than ever before to facilitate informed decision making and responsible actions at all levels; more specifically, to:

- support policy and planning (i.e. management for sustainable development) ;
- improve the application of research results;
- increase farmers' capabilities, improve farming practices and reduce externalities;
- increase public awareness of the need for sustainable development; and
- improve regional and international collaboration in matters of common concern (e.g. in pollution control, conservation of biodiversity/control of exotic species, control of epizootics/quarantine).

Past attempts at the establishment of national and regional information systems in Asia were not fruitful largely due to a lack of conviction by policy makers, planners and managers about the utility of maintaining databases and information systems (Cho, 1995). Sustainable development of information programmes requires, in the first instance, an understanding of

the essential role of information in the management of the sector. This has to be translated to commitment and political will, demonstrated by incorporation of aquaculture information policies into national aquaculture/fisheries policies, and the allocation of appropriate support. Additionally, there will be need for increasing the relevance and utility of information through consolidation and packaging of data and information in the context of the main problems and user needs.

There is an equal need for the development of effective tools and methods to manage and analyze not only disciplinary information, but also interdisciplinary and intersectoral data (e.g. decision support systems, application of GIS methods). Mechanisms are also needed to assist and promote exchange and use of information among related programmes and agencies at the national and regional levels. The strengthening of extension services and the development of novel extension mechanisms (e.g. involving co-operation between the private and public sector and/or farmer-to-farmer approaches, and integration with agricultural extension services) should command special attention. This is particularly important where the sector is largely made up of numerous small-scale practitioners, as is the case in developing countries. The promotion of associations of small-scale fish farmers would be a step forward in improving extension and communications in general.

It is understood that some of the information needed for sustainable development and management of aquaculture is not available and must be generated through research. However, considerable information on various aspects of aquaculture exists and much of this is in the grey literature. First priority should be given, therefore, to the collation and assessment of this information, increasing user access to it and, where necessary, to its repackaging into more user-friendly products.

In the near term, it is important to collect, at the national level, considerable information on economic and social aspects, resource use and efficiency, employment benefits, beneficiaries and other attributes of major aquaculture production systems to enable rational decisions to be made on integration of aquaculture into resource management plans, agriculture and rural development. This information should be aggregated, analyzed and the results packaged in usable form (possibly in the form of specific indicators) for decision makers. The specific nature and amount of information to be collected, the frequency of updating the information, and cost-effective methods for doing this, require special attention.

The sustainability of regional information systems depends first and foremost on the existence of operational national information systems. Development must first focus at the national level. Secondly, in facilitating the development/strengthening of both systems, information services and products must evolve and adapt to the needs and capacities of developing countries, and to the changes brought about by advances in information technology, to the extent that this technology can be used/afforded by those who need information most. If we let technology alone determine the approach, we will probably fail.

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1.4 Global Outlook

Pedini, M. and Z.H. Shehadeh

While recognizing the challenges discussed above, which need to be addressed by the sector, a number of indicators point to good growth potential for global aquaculture in the near term. These include:

Increasing demand: The increasing demand for fish will require more production, and the supply from capture fisheries is static.

Emergence of the sector: Aquaculture has become recognized as a growth sector of economic importance in many countries and has attracted the attention of the private and public sectors. Development plans of most producing countries are aimed at increasing fish supplies from aquaculture for local and export markets, and at increasing the sector's contribution to food security in rural areas.

Vertical expansion of production: In many developing countries, including major producers, there is (i) potential for fairly simple and relatively inexpensive means to increase production in many existing systems; (ii) an evident trend towards sustainable intensification coupled with the existence of infrastructure used for extensive traditional production, especially in Asia; and (iii) good potential for increasing productivity (e.g. through more efficient management and improved management skills, better feeds and feeding strategies, reduction of loss to disease, genetic improvement of stocks, etc.).

Horizontal expansion of production: Production areas are being expanded in China, India and other main producers, by mobilizing land resources unsuited to agriculture (saline soils, waterlogged areas, etc.), under-utilized water bodies (for cage and pen culture), seasonal water bodies, and rain-fed ponds, and by use of irrigation systems and integration with agriculture in general. In the long term, integration of aquaculture into watershed management and coastal zone management will provide growth opportunities by facilitating competitive access to resources. Horizontal expansion, though modest in the near term, will also accrue from new entrants (new producing countries).

Culture-based fisheries: Stocking of reservoirs and enhancement/rehabilitation of fisheries will gain importance with time, particularly as cost/benefit problems are resolved .

Growing awareness of sustainability needs: There is a rapidly growing awareness of the need to ensure the sustainability of the sector in the long term. Public debate involving all stakeholders, national and international efforts to arrive at practical guidelines for sustainable practices (codes of practice), and technical efforts to improve the sustainability of some aquaculture systems, are positive responses to challenges and will yield constructive results in the medium and long term.

Development prospects will vary considerably among countries and regions depending on a number of variables, discussed below; and with the increase in aquaculture production, there will be inevitable resource limitations, the impact of which will vary from country to country depending on development policies.

Translating the outlook for development into projected production levels is not a simple matter. Several key variables intervene in defining outlook at the national level, while the global outlook could be interpreted as the sum of national outlooks, modified by synergisms and antagonisms resulting from interactions between countries.

Major determining elements of development prospects at the national level include:

- *The historic perspective*, which conditions future development. That is, where aquaculture is a traditional activity, the main concern is how to ensure sustainable development of production; where it is a new activity, its adoption as a viable economic activity would be the main concern. Obviously, the consolidation of aquaculture will take much longer in countries where aquaculture is new.

- *The markets for aquaculture products*, either domestic or export. In both cases, an analysis of supply and demand for aquaculture products is required and, in the case of export markets, it is necessary to assess the country's comparative economic advantage over its competitors.

- *The perceived development issues*, which are usually determined by a detailed sector analysis. This should include physical potential for expansion and access to resources, institutional set-up and existing regulatory framework, access to funding and conditions for access to funds, availability of human skills for aquaculture production and presence of supporting industries.

- *Existing policies and national development plans* which set priorities and may include incentives and deterrents for certain forms of aquaculture.

- *Availability of technical packages for production* (new or improved) and their applicability in the country to promote additional growth of the aquaculture sector.

In the preparation of regional and global outlooks, additional elements to consider include: *how the various countries and species contribute* to the supply of aquaculture products, and *the value of the different products*, as the more expensive international commodities will have more limited market possibilities. (In these cases, market saturation is reached relatively quickly with an attendant drop in market price. Further expansion of such markets and production will be predicated on maintaining acceptable profit margins through reduction of production costs.)

The relative weights of the above elements in the assessment of development prospects vary from country to country depending on local conditions. Moreover, the aquaculture sector does not develop in a vacuum. Externalities such as macro-economic changes and social and cultural changes that occur in all the communities and which may modify attitudes of policy makers or consumers, also have an influence on the development of the sector, but are very difficult to forecast. Therefore, it is difficult to predict the course of aquaculture development in the medium and long term (over a ten-year horizon). To compound an already complex task, a considerable amount of the required information mentioned above is simply not available. As a result, projections are usually based on simplifications which limit the utility of the projected outlook.

Projections of future production from aquaculture have been attempted by various authors, with considerable simplifications based on individual approaches. In some cases estimates of *production targets* have been misinterpreted by readers as *estimates of future production.* Targets for production from aquaculture have been calculated on the basis of expected population growth and its impact on demand, assuming that consumption of fisheries products would be maintained at the prevailing per caput rate, and that food fish supply from capture fisheries would not increase significantly (New, 1991; Csavas, 1995). Attempts have also been made to make linear extrapolations of past production growth to check whether expected demand could be met (Csavas, 1995). The range of figures (for total aquaculture *production targets*) produced in these two main studies was 19.6-21.1 million mt for the year 2000, 30.0-37.6 million mt by the year 2010 and 42.0-62.4 million mt by 2025.

A different approach was attempted on the occasion of the International Conference on Sustainable Contribution of Fisheries to Food Security, held in Kyoto, Japan, in 1995. In this case, likely future production levels were estimated on the basis of projections of the future growth rates of culture of the various species groups. These rates were in turn estimated on the basis of past growth rates and production trends, as well as perceived constraints and opportunities for growth (Muir, 1995). The projected average growth rates for total global production (including plants) from 1992 to 2010, were relatively modest at APRs of 3.7 and 6.0 for the low and high growth scenarios, respectively. Projected global production, based on these rates was 37.0 million mt and 55.0 million mt, respectively. For a longer-term scenario, production by the year 2050 was estimated to be 105.0 million mt on the basis of a global APR of 3, starting from 1992 production levels. Table 1.4.1 presents a summary of these projections.

In this review we limit the time horizon for projections to a short term, five years (1995-2000). The projection is based on the FAO aquaculture statistics data base for 1984-1995.

Estimated future production by major producers

The APRs for the main commodities and for the main producing countries in 1990-1995 were used as indicators of future prospects of the main species groups and producing countries. Further insight on general development prospects was obtained from the review of future growth prospects and development plans for the sector in major producing countries, as presented in recent country statements prepared by the respective countries.

Given that in 1995 the 10 main aquaculture-producing countries accounted for 24.6 million mt, or 88% of global aquaculture production including plants, and that in the short and medium term this proportion is not likely to change significantly, it seems sufficient to examine trends in these main producers to derive an acceptable approximation of the future levels of production.

Table 1.4.2 shows the levels of production (all categories) for 1984-1995 and the APRs for the intervals 1984-1989, 1990-1995 and 1984-1995 for the 10 main producing countries. In this group, China accounts for 72.4% of production (63.4% globally) which essentially means that the future of the Chinese production is going to largely determine the prospects for global aquaculture growth. According to the statistics provided to FAO by China, the rate of growth of Chinese production has increased from an APR of 13.8 in 1984-1989 to 18.5 in 1990-1995, reaching 17.6 million mt of total production. The Government's plans to add 5 million mt to production by the year 2000 and an additional 5 million mt by 2010 appear to be possible and rather conservative in view of: the 1990-1995 growth rate; the availability of

Table 1.4.1. Summary of projected aquaculture production, 1992 to 2010 (from Muir, 1995)

				Assumed growth		Lower growth scenario		Higher growth scenario		Speculative long- term growth	
Species group	1992 Production	% of total	APR 86/92	APR 92/10	2010 mt	APR 00/10	2010 mt	APR 92/10	2010 mt	APR 92/50	2050 mt
Freshwater fish	7,980,737	84.7	7.9	4.5	17,770,000	3.7	15,400,000	5.3	20,340,000	2.2	28,280,000
Diadromous fish	1,080,698	11.5	7.6	3.8	2,130,000	3.2	1,900,000	4.8	2,510,000	2.3	3,960,000
Marine fish	355,718	3.8	7.2	5.4	910,000	3.6	670,000	11.9	2,690,000	4.7	5,100,000
TOTAL FISH	9,417,153	100	7.8	4.5	20,810,000	3.7	17,970,000	5.7	25,540,000	2.4	37,340,000
Freshwater Crustacea	62,433	6.4	1.4	5.0	150,000	4.0	140,000	5.0	150,000	4.0	610,000
Total marine Crustacea	919,483	93.6	18.6	3.3	1,650,000	2.3	1,390,000	4.4	2,000,000	1.8	2,650,000
TOTAL CRUSTACEA	981,916	100	16.8	3.4	1,800,000	2.5	1,530,000	4.5	2,150,000	2.1	3,260,000
Freshwater molluscs	256		-15.8	1.0	min	0.5	min	10.0	min	10.0	min
Marine molluscs	3,500,463	100	6.5	6.0	9,980,000	3.9	7,000,000	6.6	1,098,000	2.6	15,350,000
TOTAL MOLLUSCS	3,500,719	100	6.5	6.0	9,980,000	3.9	7,000,000	6.6	1,098,000	2.6	15,410,000
TOTAL AQ PLANTS	5,389,789	100	8	5.5	14,230,000	4.0	10,920,000	6.3	16,310,000	3.9	49,020,000
Total Aquaculture Production (Includ. plants)	19,289,577			5.1	47,000,000	3.7	37,000,000	6.0	55,000,000	3.0	105,000,000
Total Aquaculture Production (Exclud. plants)	13,899,788			4.9	33,000,000	3.8	27,000,000	5.8	39,000,000	2.4	56,000,000

Table 1.4.2. Projected production volumes (mt) and APRs (in %) of ten major producing countries.

COUNTRY	1984	1989	1995	2000	APR 84/89	APR 90/95	APR 84-95	APR 95-2000
China	3,826,026	7,293,728	17,581,642	22,500,000	13.8	18.5	14.9	5.1
India	510,000	1,004,500	1,608,938	2,400,000	14.5	9.7	11.0	8.0
Japan	1,198,692	1,359,345	1,381,082	1,400,000	2.5	0.3	1.3	0.0
Korea Rep.	667,685	821,778	990,498	1,220,000	4.2	5.5	3.7	4.0
Philippines	478,345	629,323	812,325	1,000,000	5.6	3.9	4.9	4.0
Indonesia	330,764	521,075	719,410	875,000	9.5	3.7	7.3	4.0
Thailand	111,930	260,185	464,173	680,000	18.4	9.7	13.8	8.0
USA	326,453	369,052	413,431	500,000	2.5	5.6	2.2	4.0
Bangladesh	117,025	162,630	321,506	475,000	6.8	13.6	9.6	8.0
Taiwan (PC)	244,806	243,996	283,540	300,000	-0.1	-3.8	1.3	0.0
TOTAL (less China)	3,985,700	5,371,884	6,994,903	8,850,000	6.2	4.8	5.2	4.8
TOTAL	7,811,726	12,665,612	24,576,545	31,350,000	10.1	13.5	11.0	5.0
Other countries	2,311,903	2,463,398	3,138,943	3,640,000	1.2	2.8	2.7	3.0
GRAND TOTAL	10,123,629	15,129,010	27,715,488	34,990,000	8.4	12.1	9.6	4.8

area for expansion in inland areas (72% has been utilized so far) and coastal areas (32% occupation of potential space); the potential to improve yield in the northern part of thecountry; and the Government's plans for investment for expansion of the sector and supporting industries for aquaculture (Zhao, 1997).

The contribution of the other nine countries to global aquaculture in 1995 was 7 million mt and the picture is radically different from that of China. The APR for these countries was 6.2 for 1984-1989 and 4.8 for 1990-1995. The latter is more or less in line with the global growth rate excluding China (i.e. 4.4 for 1990-1995). Growth prospects are uneven. India, Thailand and Bangladesh show relatively high APRs in the 1990-1995 period, ranging from 9.7 to 13.6, for a total joint production of about 2.4 million mt in 1995. It could be expected that an average APR of about 8 could be maintained in the short term by these three countries, as they have potential for expansion in both domestic and export markets, and potential for sustainable intensification of their productions levels, in particular in India and Bangladesh (Liaquat Ali, 1997; Yugraj Singh, 1997). In Thailand the potential for expansion of shrimp culture is rather limited but this is expected to be offset by a shift in production towards mollusc culture and freshwater aquaculture products (Tookwinas, 1997). This projected growth rate should result in production of 3.6 million mt from the three countries by the year 2000.

Japan (Anon., 1997) and Taiwan Province of China (PC), are unlikely to achieve any significant growth in the short term over the levels reached in 1995, because the areas for production seem to be saturated and the level of production is already quite intensive, something which has led to environmental problems and disease outbreaks in Taiwan (PC). Thus, by the year 2000, production for these two countries would be about 1.7 million mt (i.e. the same as in 1995).

The third group among the nine major producers includes the Republic of Korea, the Philippines, Indonesia and the USA, with APRs of 3.7 to 5.6 for 1990-1995. An APR of 4 to the year 2000 appears likely in view of good market prospects , possibilities for expansion of production areas (although relatively less area is available in the Philippines (Aypa, 1997)), good prospects for intensification of production, and access to funds for further development. This will bring expected production from these countries to 3.6 million mt.

Accordingly, the aggregated production of the ten major countries for the year 2000 is expected to reach no less than 31.3 million mt. The rest of the 164 countries reporting aquaculture production contributed 3.1 million mt in 1995 and could be expected to have a conservative APR of 3 in the short term. This implies a production of about 3.6 million mt by year 2000. Thus, with an average global APR of 4.8 for 1995-2000, the total expected global aquaculture production (including plants) by the year 2000 would be about 35 million mt (Table 1.4.2). This should be considered a conservative estimate.

Growth prospects of major species groups

Of the 292 species included in the 1995 FAO aquaculture statistics for which production statistics are provided by member countries, the first 22 species accounted for 80% of the production in 1995 (Table 1.4.3), and the first 31 for 90%. Of the first 22 species, nearly all of the farmed animals are either filter feeders, herbivores or omnivores. Only one species, Atlantic salmon, is carnivorous and it is clearly a minor species in terms of production volume.

The most important group is freshwater finfish (Table 1.4.4). Cyprinids dominate in this group, with a contribution of over 10.3 million mt in 1995. APRs for the various species for 1990-1995 range from 9.7 to 20 (Table 1.4.3). Cyprinids have a number of advantages which will maintain their leadership in the short and medium term: they can use feeds with moderate protein and fishmeal content; they can be reared in polyculture systems that make optimum use of the natural productivity of ponds and water bodies where they are stocked; and they have good markets in Asian countries, due to traditions and relatively low prices.

Aquatic plants have experienced a strong comeback after a period of stagnation in 1984-1989. The APR of 15.8 in 1990-1995, due to the rapid growth of *Laminaria japonica* and *Porphyra tenera* farming, underlines renewed interest in this group. Coastal areas where these plants could be farmed are far from saturated, and this group could gain more importance in the future, mainly in the Far East.

Mollusc culture also showed an increasing APR in 1990-1995, averaging about 11.4. This is due in particular to the rapid expansion in the production of scallops and clams, while production of more traditional products like oysters and mussels have suffered from environmental problems (red tides mainly) that have limited their marketability. Clams and scallops will probably gain a larger share in the mollusc group also due to good market price and an international market, and the availability of farming areas. However, expansion of mollusc culture may be threatened by the deterioration of water quality in coastal areas, which may limit the marketability of the products, as has already happened with mussels and oysters. It is likely that the overall growth for 1995-2000 will decline by an APR of 2-3 below that of 1990-1995.

Crustacean culture experienced very rapid growth (APR 24.8) in the mid-to-late 1980s, but growth declined sharply (APR about 8) in 1990-1995 due to viral diseases and environment related problems not yet overcome. Prospects for this group will probably be limited by difficulties in expanding the areas under culture due to problems associated with the very intensive industrial forms of culture (social conflicts, coastal pollution, disease outbreaks) and the attention that the international media have given to these problems. It is also likely that semi-intensive forms will gain ground in the short or mid term, due to current resistance to intensification. In the short term it is further possible that while some areas are recovering from sudden losses, others may suffer viral epidemics, resulting in discontinuous progress in

production. Overall, these constraints will probably be reflected in a decline in growth rates below the 1990-1995 levels.

Table 1.4.3. Production of major species (mt) and APRs (%)

Species	1984	1987	1990	1993	1995	APR 84/89	APR 90/95	APR 84-95
Laminaria japonica	2,024,649	1,582,962	1,638,217	3,788,108	4,055,027	-2.2	19.9	6.5
Hypophthalmichthys molitrix	835,543	1,438,542	1,504,192	1,904,575	2,555,407	11.8	11.2	10.7
Ctenopharyngodon idellus	297,761	543,646	1,046,677	1,496,607	2,102,652	26.3	15.0	19.4
Cyprinus carpio	614,438	1,046,703	1,136,980	1,331,075	1,803,256	10.5	9.7	10.3
Osteichthyes	263,140	306,924	599,919	985,312	1,275,361	16.7	16.3	15.4
Aristichthys nobilis	377,158	647,147	676,797	923,537	1,256,930	11.6	13.2	11.6
Pecten yessoensis	77,801	196,109	339,169	969,933	1,144,428	31.8	27.5	27.7
Crassostrea gigas	674,114	808,759	755,385	870,854	1,001,064	2.5	5.8	3.7
Porphyra tenera	636,534	500,489	540,322	794,463	909,122	0.1	11.0	3.3
Algae	57,784	184,110	217,337	627,183	654,409	18.6	24.7	24.7
Mollusca	36,411	110,015	156,199	168,677	558,165	31.5	29.0	28.2
Carassius carassius	58,995	108,915	215,579	294,546	537,541	28.8	20.0	22.2
Ruditapes philippinarum	43,609	111,953	174,349	443,139	521,219	28.8	24.5	25.3
Penaeus monodon	53,692	155,356	251,127	436,637	502,701	33.0	14.9	22.5
Undaria pinnatifida	494,774	416,003	389,807	469,763	495,390	-4.3	4.9	0.0
Oreochromis niloticus	66,281	122,862	224,984	378,889	473,641	24.4	16.1	19.6
Salmo salar	27,404	68,105	225,480	312,325	471,813	43.5	15.9	29.5
Labeo rohita	135,433	189,327	243,428	411,495	458,795	12.4	13.5	11.7
Mytilidae	136,587	312,686	495,937	510,571	415,957	29.1	-3.5	10.7
Eucheuma cottoni	122,537	189,922	250,411	327,719	401,920	13.5	9.9	11.4
Catla catla	129,000	181,000	234,003	341,604	381,143	12.6	10.2	10.4
Cirrhinus mrigala	88,003	123,109	158,857	334,552	373,017	12.4	18.6	14.0
TOTAL	7,251,648	9,344,644	11,475,156	18,121,564	22,348,958	9.0	14.3	10.8

Diadromous fish form a relatively stable aquaculture group with a trend to decreasing growth rate. The APR for 1990-1995 was 4 and it is likely that short-term prospects will not be very different.

Culture of marine finfish has attracted considerable attention in the last decade with a higher growth rate in 1990-1995 than in 1984-1989 (Table 1.4.4). This has been due to the promotion of cage culture and to the improvement of seed production techniques, which has increased the number of species for which commercial hatcheries are available. The potential for expansion will probably be limited by competition for coastal sites (except in the case of offshore cages), feed availability, and environmental concerns, including pollution by other sectors. The economics of production also present problems as many of these species are relatively expensive to produce and, therefore, relatively limited niche markets are targeted. Marine ranching of both demersal and large pelagic species remains limited in the short term by difficulties in mass production of fry, questionable economic viability and legal problems linked to fish ownership. Technological breakthroughs linked to genetics, engineering and feed development, as well as supportive development policies and plans, appear to be needed to guarantee that this group will be able to maintain its present growth rate. The prospects in the short term are thus for a reduction in the growth rate of this group.

Accordingly, it is expected that inland (freshwater) aquaculture will continue to provide the major share of output in the form of low to moderately priced herbivorous/omnivorous species (especially carps), grown mostly in ecologically efficient and environmentally benign polyculture systems. This form of aquaculture will continue to supply substantial quantities of fish protein for large segments of the population in many developing countries and will probably be the primary area of development for lower cost production.

Table 1.4.4. Production (mt) by commodity group and APRs (%).

Groups	1984	1989	1995	APR 84/89	APR 90/95	APR 84/95
Freshwater Fishes	3,557,718	6,855,331	12,727,038	14.0	12.0	12.3
Aquatic Plants	3,446,524	3,415,895	6,812,879	-0.2	15.8	6.4
Molluscs	1,997,002	2,943,729	5,087,068	8.1	11.4	8.9
Diadromous Fishes	680,903	932,071	1,388,539	6.5	4.0	6.7
Crustaceans	231,798	702,292	1,126,632	24.8	8.1	15.5
Marine Fishes	209,684	282,692	573,332	6.2	13.2	9.6
TOTAL	10,123,629	15,132,010	27,715,488	8.4	12.1	9.6

Coastal and marine aquaculture will probably come under increasing pressure for environmental control, social benefit and site availability, particularly in the case of high-value species (shrimp and marine finfish) and will probably affect the production of these species. This is likely to stimulate other production, for a different market, using technologies at lower levels of intensity with lower environmental impact, such as polyculture systems and species at lower trophic levels, including molluscs and aquatic plants.

Better policy and planning are needed to improve prospects for equitable, efficient and sustainable development, while more co-ordinated approaches will be required to stimulate development and achieve high growth rates.

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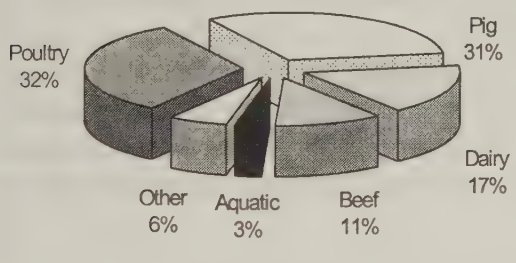
2. SELECTED DEVELOPMENTS AND TRENDS

2.1 Aquafeeds and Feeding Strategies

Tacon, A. G. J.

There has been a growing trend within most developing countries and many developed countries (e.g. Japan) toward the increased use of artificially compounded feeds (aquafeeds) for farmed finfish and crustaceans. This trend has been particularly apparent within developing countries with the progressive intensification of farming systems, and in particular within the main LIFDC[1] finfish- and crustacean-producing countries (i.e. China, India, Indonesia and the Philippines) for the production of both lower-value staple food fish species (mainly freshwater finfish such as carp, tilapia and catfish) and higher-value cash crop species for luxury or niche markets (mainly marine and diadromous species such as shrimp, salmon, trout, yellowtail, seabass, seabream and grouper). In fact, the production of aquafeeds has been widely recognized as one of the fastest expanding agricultural industries in the world, with annual growth rates in excess of 30% per year (Rabobank Nederland, 1995; Tacon, 1996).

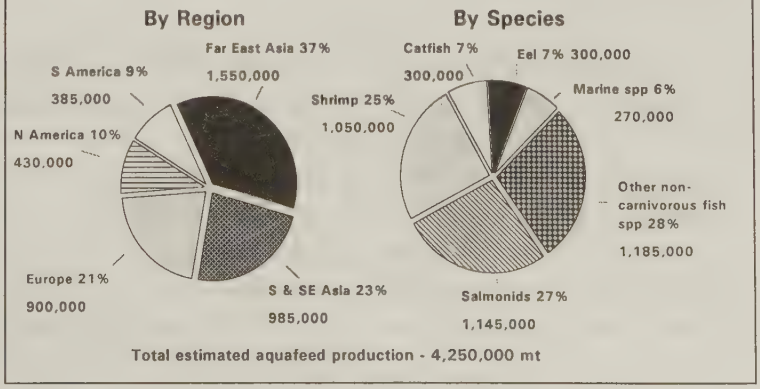
Figure 2.1.1. Estimated global use of manufactured animal feeds for major animal groups in 1995 (Gill, 1996)



Although no official statistics are currently collected by FAO concerning compound animal feed production within its Member States (including the production of farm-made and commercially compounded aquafeeds), it has been estimated by Gill (1996) that the total world production of manufactured compound animal feeds was about 560 million mt in 1995 (valued at over US$55 thousand million), of which aquatic feeds constituted 3% or 16.8 million mt (Figure 2.1.1). Gill (1997) estimated global aquafeed production to be 18.2 million mt in 1996, although no information was provided as to the quantities of aquafeeds produced for the different major cultivated species within individual countries or regions.

Estimates of global aquafeed production by major feed ingredient suppliers and workers from within the aquaculture sector have been considerably lower, ranging from 3.34 million mt in 1992 (New and Csavas, 1995), 3.57 million mt in 1994 (Pike, 1997), 4.25 million mt in 1994 (Smith and Guerin, 1995), to 6 million mt in 1996 (Feord, 1997). Smith and Guerin (1995) estimated that about 60% of the total aquafeed production in 1994 was produced in Asia (37%) and Europe (21%), with over half of the

Figure 2.1.2. Estimated global aquafeed production (mt) in 1994 (Smith & Guerin, 1995)



[1] Low-income food deficit countries

aquafeed produced being for salmonids (27%) and shrimp (25%), followed by catfish (7%), eel (7%), marine finfish (6%), and other non-carnivorous finfish (carp, tilapia, milkfish, etc., 28%) (Figure 2.1.2). On the basis of dietary feeding habit, 40% of total aquafeed production was for carnivorous finfish species, 35% for non-carnivorous finfish species (including catfish), and 25% for shrimp.

Projections for aquafeed production for the year 2000 have been made by several authors and range from 4.5 million mt (a 35% increase from 1992; New and Csavas, 1995), 4.6 million mt (a 56% increase from 1990; Chamberlain, 1993) to 7.5 million mt (assumes a modest annual growth of 10% per year or a 78% increase from 1994; Tacon, 1996).

In general, the major global challenges currently facing aquafeed development are as follows:

- **The need for aquaculture to be seen as a net contributor to total world fisheries landings and global food supply rather than a net consumer of potential food-grade fishery resources**

In contrast to the majority of freshwater farming systems, almost all production systems for brackishwater or marine finfish and crustaceans (i.e. diadromous and marine species) are dependent upon capture fisheries for sourcing their inputs through: a) the capture of wild broodstock for spawning (most penaeid shrimp and marine finfish farming); b) the collection of wild `seed' for subsequent on-growing to market size, such as milkfish, yellowtail, mullet, eels, groupers, etc., and most types of extensive penaeid shrimp farming; and c) the use of whole or processed fishery products as feed inputs (Tacon and Barg, in press). At present, nearly all farming operations for carnivorous diadromous finfish, marine finfish and crustaceans, which are based upon the use of aquafeeds, are net fishery resource `reducers' rather than `producers'. The quantity of inputs of dietary fishery resources in the form of fishmeal, fish oil, crustacean by-product meals, `trash fish', etc., exceeds outputs in terms of farmed fishery products by a factor of 2 to 3.

Production of the 3 million mt of farmed marine/diadromous finfish/crustacean species (wet basis) in 1995 would have required over 1.5 million mt of fishmeal and fish oil (dry basis) or the equivalent of over 5 million mt of pelagic fish (wet basis; assumes a pelagics to fishmeal conversion factor of 5:1). This is not surprising because fishmeal and fish oil usually constitute 50-75% by weight of compound aquafeeds for most commercially farmed carnivorous finfish species and 25-50% by weight (together with shrimp meals and squid meal) of compound aquafeeds for marine shrimp. This conversion of pelagic biomass to fishmeal used for aquafeeds results in the `double counting' of fish production, once as capture fishery landings and again as aquaculture production.

- **The need for finfish and crustacean farming systems to develop feeding strategies based wherever possible upon the use of non-food grade locally available feed resources**

Despite the superior nutritional and economic merits of feeding regimes based upon the use of fishery resources as feed inputs for carnivorous fish and marine shrimp, the future availability and cost of these feed ingredients are both uncertain and unstable. Despite optimistic projections made by the fishmeal and fish oil manufacturing industry concerning the availability and use of these fishery products for animal feeds (including aquafeeds) over the next decade (Tables 2.1.1-2.1.3, Figure 2.1.3; Pike, 1997), there are increasing doubts regarding the long-term sustainability of farming systems based entirely upon these finite and valuable fishery resources, in particular concerning the efficiency and ethics of feeding potentially food-grade fishery

resources back to animals (including fish) rather than feeding them directly to humans (Best, 1996a; Hansen, 1996; Pimentel et al., 1996; Rees, 1997).

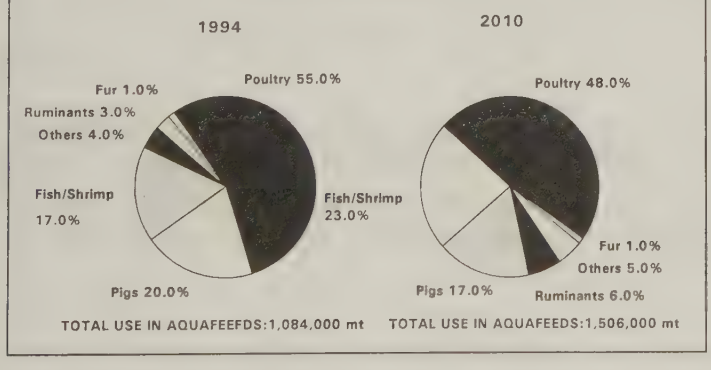
In the short term, efforts could be focused on the potential use of non-food grade fishery by-products (i.e. fishery by-catch and discards, and fishmeals produced from fish processing plants and industrial non-food fishes [Alverson et al., 1994; New, 1996]). Clearly, however, the long-term efforts must be placed on the use of by-products from the much larger and faster-growing terrestrial agricultural production sector, including: 1) terrestrial animal by-product meals resulting from the processing (i.e. rendering) of non-food grade livestock by-products; 2) plant oilseed and grain legume meals; 3) cereal by-product meals; and 4) miscellaneous protein sources such as single-cell proteins, leaf protein concentrates, invertebrate meals, etc. However, the eventual success of these potential feed resources as fishmeal replacement in aquafeeds will in turn depend upon the further development and use of improved techniques in feed processing/manufacture (Riaz, 1997; Watanabe and Kiron, 1997) and feed formulation, including the increased use of specific feed additives such as feeding stimulants, free amino acids, feed enzymes, probiotics and immune-enhancers (Devresse et al., 1997; Feord, 1997; Hardy and Dong, 1997).

Table 2.1.1. Estimated use of fishmeal by farmed animals, 1994 and 2010, as percentage of total used (Pike, 1997).

Group	1994	2010
Poultry	55	48
Pigs	20	17
Fish and shrimp	17	23
Ruminants	3	6
Fur	1	1
Others	4	5
Total use in aqua-feeds (mt)	1,084,000	1,506,000

Moreover, in developing countries, efforts should be made whenever possible to upgrade, through the use of improved processing methods, and increase the use of locally available feed ingredient sources so as to reduce the current dependence of most developing countries upon imported sources (Rabobank Nederland, 1995; Best, 1996b). For example, in a recent survey of the aquaculture feed manufacturing sector in the Philippines, it was estimated that approximately 45-75% of the ingredients used in commercial aquaculture feeds for finfish (mainly tilapia and milkfish) and 85-95% of those for marine shrimp were imported, as compared with only 20-30% for livestock and poultry feeds (Cruz, 1997). However, in marked contrast to commercially produced aquafeeds, the local production of farm-made aquafeeds by small-scale farmers plays an important role in that it does facilitate the use of locally available feed ingredient sources and agricultural by-products that would otherwise not be used (New et al., 1995).

Figure 2.1.3. Estimated total use of fishmeal by farmed animals 1994 & 2010 (Pike, 1997)



Clearly, if the finfish and crustacean aquaculture sector is to sustain its rapid growth rate (11.7% per year since 1984) into the next millennium, the aquafeed manufacturing sector will have to compete successfully with other users, including humans and the much larger animal livestock production sector (see Figure 2.1.1) for available feed resources. Therefore, in the coming decade, the aquaculture sector will have to base its feeding regimes upon the use of feed

ingredient sources whose global production and availability can keep pace with the increasing needs of a growing and hungry world. For example, in terms of global protein supply, soybean meal production has been growing more than four times faster than has fishmeal production: an average annual growth rate between 1984 and 1995 of 4.6% from 56.7 to 93.40 million mt, compared with 1.1% from 6.11 million mt to 6.87 million mt for fishmeal production (Figure 2.1.4). In addition, it is generally expected that strong demand from Asia, and in particular from China, for available feed resources will have a considerable impact on world commodity markets and feed prices (Brown, 1995; Rabobank Nederland, 1995; Gill, 1997). China is the world's largest importer of fishmeal (ca. 0.88 million mt in 1996; Buckley, 1997) and is the world's second largest compound animal feed manufacturer (ca. 42-48 million mt in 1995). Its feed production is expected to expand to more than 100 million mt by 2005 (Anon., 1997a, 1997b) and 120-150 million mt by 2010 (Zhang Yu, 1996). The official government estimate for aquafeed production in China in 1994 was 1.85 million mt (5% of total compound feed production; Zhang Yu, 1996); unconfirmed estimates for aquafeed production in China in 1996 exceed 5 million mt.

Table 2.1.2. Estimated percentage of fishmeal used by farmed fish and shrimp, 1994 and 2010 (Pike, 1997).

Species	1994	2010
Salmon	32.4	31.9
Shrimp	22.2	39.0
Trout	15.8	9.3
Eels	8.6	3.1
Bream/bass	5.3	4.8
Carp	4.1	3.4
Yellowtail	3.9	1.8
Catfish	2.0	0.8
Others	5.6	5.8
Total use in aqua-feeds (mt)	1,084,000	1,506,000

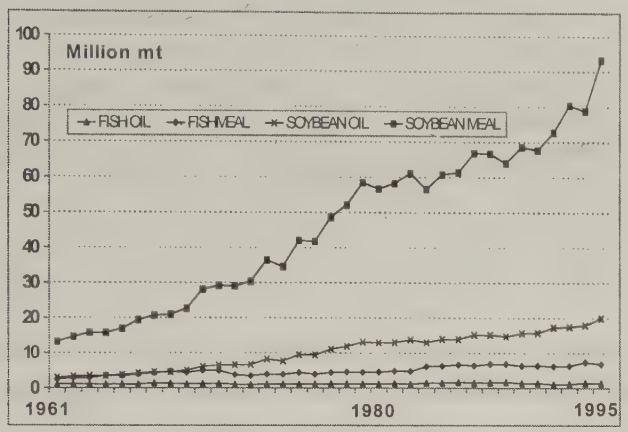
Table 2.1.3. Estimated percentage of fish oil used by farmed fish and shrimp, 1994 and 2010 (Pike, 1997).

Species	1994	2010
Salmon	44.5	42.4
Trout	23.9	12.4
Carp	7.9	11.0
Shrimp	7.6	13.0
Eels	5.0	1.4
Bream/bass	3.2	3.2
Yellowtail	2.1	9.5
Catfish	2.1	1.1
Others	3.7	6.1
Total use in aqua-feeds (mt)	380,000	1,133,000

- **The need for development of improved feed formulation and on-farm feed and water management strategies tailored to the needs of the intended farming system or farm production unit, in order to minimize feed wastage and its potential negative effect on the aquatic environment, and to maximize nutrient retention and the health status of cultured organisms**

As farming systems intensify, either in terms of increased stocking density and consequent nutrient input or in terms of number of farms per unit area, the need for development of environmentally cleaner or 'greener' feeding strategies becomes greater. The net result of excess nutrient loss is an economic loss to the farmer, and a potentially deteriorating aquatic environment within and possibly outside the farm, with consequent increased stress to the cultured animals and increased susceptibility to disease. Thus, feeding regimes should be designed to minimize nutrient loss and faecal output, and to maximize nutrient retention and the health status of the cultured species. Such actions would in turn help to improve the social acceptance and confidence of the sector in terms of aquatic resource use and environmental sustainability (Tacon et al., 1995).

Figure 2.1.4. World production of fishmeal, fish oil, soybean meal and soybean oil, 1961 - 1995



Source: FAO Commodity and Trade Division/Fisheries Information and Statistics Division ESC/FISHDAB Databases, June 1997

In this respect, feed manufacturers have the very important responsibility of ensuring that the feed they provide to farmers is both nutritionally correct for the intended farming production system, and is managed correctly by the farmer. Feed manufacturers can contribute to reducing the environmental impact of aquaculture by: 1) providing information to promote efficient husbandry in order to reduce wastage through uneaten food; 2) optimizing nutrient retention by improving digestibility of nutrients and dietary nutrient balance; 3) producing palatable feeds; 4) adopting feed-processing technology that will reduce leaching, dust and pellet disintegration; and 5) minimizing fish mortality through the development of health-promoting diets (Talbot and Hole, 1994).

At present, most commercially available aquafeeds for extensive and semi-intensive pond farming systems are over-formulated as nutritionally complete diets, irrespective of the intended fish or crustacean stocking density and consequent natural food availability. Clearly, this situation will have to be rectified if farmers are to minimize feed wastage and the deposition of uneaten feed and potentially toxic pond sediments, thus reducing production costs and maximizing returns. The important message here is for feed manufacturers and on-farm feed compounders to tailor the feed to the intended farming system and not just to the theoretical requirements of a fish or shrimp with no access to natural food (Chamberlain and Hopkins, 1994; Anderson and De Silva, 1997; Chamberlain, in press; Tacon and Basucro, 1997).

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2.2 Fish Health and Quarantine

Subasinghe, R.

Disease outbreaks are being increasingly recognized as a significant constraint to aquaculture production and trade and are affecting economic development of the sector in many countries of the world. Disease is now considered to be the most limiting factor in the shrimp culture sub-sector. Some figures are available on direct economic losses which indicate the significance of the problem, although social and other related impact, such as trade and employment issues, chemical and drug use, and environmental costs, has never been properly quantified. Estimates of economic losses suggest that developing countries in Asia lost at least US$1.4 thousand million due to diseases in 1990 alone. Since then, losses have increased. Reports from China suggest losses in 1993 of US$1 thousand million due to shrimp viral disease outbreaks (ADB/NACA, in press). A 1995 estimate suggests that aquatic animal disease and environment-related problems may cause annual losses to aquaculture production in Asian countries of more than US$3 thousand million per year (ADB/NACA, in press). According to a recent World Bank report, global losses due to shrimp disease are around US$3 thousand million and the Bank recommends investment of US$275 million in shrimp disease research over the next 15 years (Lundin, 1996).

The above figures provide an indication of the overall economic significance of aquatic animal diseases. However, there is need for a much more systematic review and analysis of information on their social and economic impact, and on the cost-benefits of alternative control strategies. There is also a need to develop a better framework or methodology for routine data collection and reporting on the incidence and socio-economic impact of aquatic animal diseases.

Major diseases and epizootics

Epizootic ulcerative syndrome (EUS) is one of the most severe fish diseases in Asia; it has a complex infectious aetiology and causes a seasonal epizootic condition in over 100 species of wild and farmed freshwater and brackishwater fish. The disease has caused severe economic losses in Asia and is now endemic to Southeast and South Asia, and has recently extended to West Asia. Control of EUS in natural waters is probably impossible, although various preventative measures can be used to reduce the risk of spread of EUS to some natural water bodies. The causative agent of EUS is the fungus *Aphanomyces* variably termed *A. piscicida* and *A. invaderis* (OIE, 1997). From the little epidemiological data available, it appears that the disease is spread by movement of water or, in certain cases, movement of fish without adequate quarantine and health certification (Arthur, 1996).

Monodon baculo virus (MBV) outbreak in Taiwan Province of China in 1988, followed by a series of shrimp viral disease outbreaks--Yellow-head virus (YHV) in 1992 in Thailand, Taura Syndrome virus (TSV) in 1992 in Ecuador, white spot virus (WSV) in 1993 in China and Thailand, and the same virus in a number of other Asian countries since 1993--have caused severe production losses to the global shrimp culture industry. At present over 20 viruses have been identified as important to shrimp, the most threatening being WSV in Asia and TSV in the Americas.

Many more disease outbreaks have been reported in other parts of the world, under culture and in the wild. Notable are furunculosis in salmonids, sea lice infections in European cage-cultured marine fish, and the recent Noda virus epizootic in seabass. Besides reported losses at epizootic

levels, day-to-day loss of production due to infectious and non-infectious diseases, both at commercial and subsistent production levels and in the wild, is probably highly significant.

Need for a new approach to health management

Environmental factors and poor water quality resulting from increased effluent discharge, movement of aquatic animals, inadequate farm management, rapid proliferation of farms, etc., have been implicated in major disease outbreaks occurring in epizootic conditions. However, the underlying causes of such epizootics are highly complex and difficult to pinpoint. An understanding of the relationship between host, pathogen and environment is important in this regard. Since aquatic animal disease is the end result of a series of linked events, treatment of disease should go beyond consideration of the pathogen alone. Conventional approaches have so far had limited success in the prevention or cure of aquatic disease. Recent experience in trying to control disease outbreaks clearly demonstrates the importance of the linkage with other components of the production system, including the need for, *inter alia,* broader ecosystem management approaches to control farm-level environmental deterioration and to take preventative measures against the introduction of pathogens--the "systems management approach" (SMA) to aquatic animal health (Phillips, 1996).

The emphasis of SMA should be on better management for prevention, which is likely to be more cost effective than cure, involving both on-farm management and the management of the environment where farms are located. Government inputs are essential for regulation of resource use, particularly land and water, and for helping to provide legal and institutional arrangements that minimize resource-use conflicts and control environmental impact of and on aquaculture. Wider adoption of such approaches may lead to sustainable solutions that can be adopted by farmers, and to less reliance on the use of chemicals, which largely treat the symptom of the problem and not the cause. In addition, research, training programs, extension, and information exchange can be more effective and responsive to farmers' needs if based on SMA. The FAO's Code of Conduct for Responsible Fisheries is an ideal platform to link SMA and national/international cooperation in harmonizing aquatic animal health management activities (Subasinghe et al., in press).

Recent developments in disease control

Over the years, significant achievements have been made through collaboration and cooperation between developed and developing countries in finding tools to combat or control diseases in aquaculture. However, there is still considerable scope for further improvement of such collaboration in developing new tools and perfecting existing ones. Major areas for further research include: a) quality control and more efficient and cost-effective use of inputs, such as water, seed and feed; b) the role of good nutrition in improving aquatic animal health; c) harnessing the host's specific and non-specific defence mechanisms in controlling aquatic animal diseases; d) development of affordable yet efficient vaccines for economically important tropical fish; e) use of immunostimulants and non-specific immune-enhancers to reduce susceptibility to disease; and f) use of probiotics and bioaugmentation for the improvement of aquatic environmental quality. The results of this research will undoubtedly help reduce chemical and drug use in aquaculture, and will not only contribute towards reducing negative environmental impact of chemical use, but will also make aquaculture products more acceptable to consumers.

Immunological assays, including fluorescent antibody techniques (FAT) and enzyme linked immunosorbent assays (ELISA), are presently used for sensitive and rapid detection of various fish pathogens. In addition, new assays from genetic engineering using nucleic acid probes are evolving from medical diagnostics. Reports have shown that polymerase chain reaction (PCR)

techniques--which can greatly multiply minute quantities of DNA--combined with DNA probes, are effective in detecting the presence of nucleic acid sequences of fish and shrimp pathogens from infected tissues. The recent development of a PCR for the detection of WSV is a major breakthrough in combating the shrimp viral epizootic. There are two trends: (a) kits are becoming available for farmers to use on location to obtain information quickly about the presence of pathogens; and (b) central laboratories with trained staff are being organized to receive fresh and preserved samples from distant locations for processing and identification of unusual or difficult-to-detect antigens or nucleic acid sequences. Over the next decade, the potential for developing cost-effective and affordable, yet sensitive and effective, rapid diagnostic tools for use in developing-country situations will increase, as will joint commercial ventures between developed and developing countries for this purpose.

The application of genetic technologies in aquaculture is a recent practice for all but a few aquatic species. These technologies can be applied as part of SMA to fish health, to increase disease resistance, and to act as diagnostic tools to confirm the presence or absence of specific pathogens.

Quarantine and health certification

Quarantine and health certification programs form part of a first line of defense against possible adverse effects resulting from the introduction or transfer of exotic fish and shellfish. As such, they must be developed within the context of larger national, regional, and international plans addressing this problem. "Codes of practice" for the introduction and transfer of aquatic organisms that have been developed by international organizations, provide a starting point for designing national fish health legislation and for international agreements to prevent the spread of disease. To succeed, such efforts must be accompanied by the development of regionally agreed-upon lists of certifiable pathogens, the standardization of diagnostic techniques and the production of health certificates of unambiguous meaning. Establishment of intra- and inter-regional fish health information systems which could be linked with those of relevant regional and international agencies would be highly desirable for the success of such efforts. Strong commitment by national governments and the cooperation of importers/exporters are keys to the success of these programs. Successful disease prevention will also be directly related to the ability of countries to reduce their dependence on imported broodstock and fry for aquaculture.

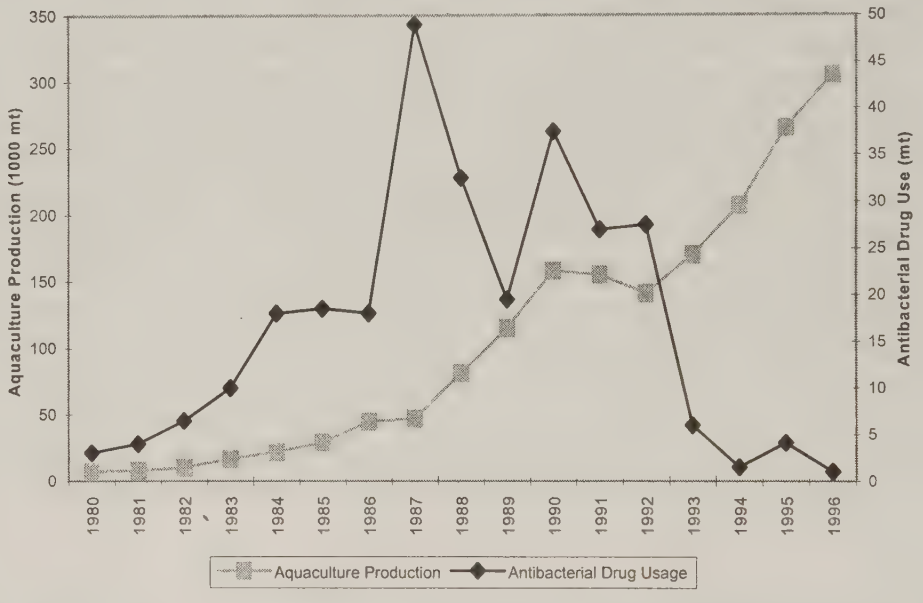
FAO, in collaboration with the Network of Aquaculture Centres in Asia-Pacific, has developed a strategy for a cooperative framework, comprising key fisheries and veterinary authorities in countries of the region, and which may be used to implement the adopted uniform regional quarantine practices (Subasinghe et. al., in press). Agencies such as the Office International des Epizooties (OIE), UK Department of International Development, Australian Centre for International Agricultural Research, Fish Health Section of the Asian Fisheries Society, and Aquatic Animal Health Research Institute are supporting this initiative. The main objective of the above strategy is to develop practical and effective regional and national health certification and quarantine guidelines that will minimize the negative impact of aquatic animal diseases on production from aquaculture, inland and coastal capture fisheries, and indigenous aquatic biodiversity, as well as increase the income of aquaculturists in the region, the majority being small-scale farmers. There are activities underway to establish similar regional networks in Latin America with possible assistance from agencies such as the World Bank, European Union and FAO (Subasinghe and Arthur, 1997).

Use of drugs and other chemicals

Many chemicals are being used in aquaculture. Some are essential for successful and efficient farm and hatchery management, and some have been widely used in agriculture without adverse

impacts. Most chemicals used do not appear to carry any significant potential for adverse effects on human health or environment, provided that they are applied in a technically appropriate manner (GESAMP, 1997). Although, in general, use of antimicrobial drugs in aquaculture is rapidly decreasing in major producing countries such as Norway (Fig. 2.2.1) (Anon., 1997), there are considerable constraints to the promotion of safe and effective use of drugs and chemicals in aquaculture in developing countries. They include: a) lack of trained manpower and related capacity-building schemes and support services to disseminate information on fish health management; b) the misapplication of some chemicals (e.g. the excessive prophylactic use of antibacterials); c) insufficient understanding of mode of action and efficacy of certain chemicals, especially under tropical aquaculture conditions; and d) uncertainties with regard to legal and institutional frameworks to govern chemical use in aquaculture (Barg and Lavilla-Pitogo, 1996).

Figure 2.2.1. Trends in aquaculture production and drug use in Norway



Implications for international trade

The use of drugs and other chemicals in aquaculture, quarantine and health certification of live aquatic animals during their transboundary movements, and screening of aquatic animals and animal products for human pathogens have become significant issues in international trade following the recent General Agreement on Tariffs and Trade and the "international agreement on application of sanitary and phytosanitary measures" (SPS Agreement) (GATT Secretariat, 1994). The SPS Agreement recognizes international agencies such as FAO, WHO, and OIE as reference points in solving trade disputes over such issues. Over the next decade, these agencies will play significant roles not only in solving trade disputes, but also in developing relevant technical guidelines and providing technical assistance to their member countries on issues relevant to the mandates of these organizations.

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2.3 Biodiversity and Genetics

Bartley, D.

The importance of biodiversity, which includes the diversity of genes, species and ecosystems, has recently been acknowledged by the entry into force of the Convention on Biological Diversity in 1993, by the acceptance of the FAO Code of Conduct for Responsible Fisheries in 1995, and by the expansion, also in 1995, of the FAO Commission on Plant Genetic Resources to include all genetic resources for food and agriculture. To assist in these international fora and to fulfil FAO's mandate to Member States, the Fishery Department is undertaking work on genetic resources in four main areas: i) documentation and characterization of aquatic biodiversity; ii) identification of threats and opportunities; iii) identification and evaluation of new technologies; and iv) identification of trends (Bartley and Welcomme, 1996).

Although genetic improvement of common carp probably started several thousand years ago, the application of genetic principles to most aquaculture species is a relatively recent phenomenon. Thus, the majority of farm-raised aquatic animals and plants are very similar to their wild forms. Genetic improvement programmes are beginning to be applied to more and more aquatic species, but when compared to the levels of domestication in livestock and crops, the aquatic sector is still far behind. The number of farmed taxa for which data are reported to FAO has increased for all major groups since 1984: 34% for fishes, 29% for crustaceans, and 31% for molluscs (Garibaldi, 1996) (Figure 2.3.1). As domestication extends to more and more species, so will the application of genetic improvement technologies.

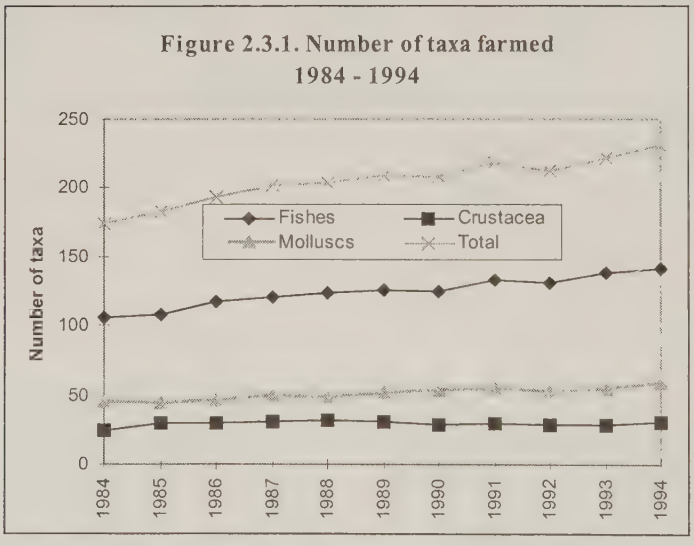


Figure 2.3.1. Number of taxa farmed 1984 - 1994

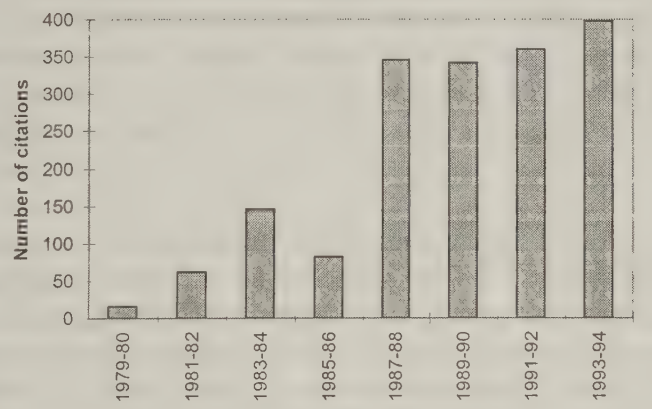
Documentation and characterization of the biodiversity of aquatic organisms are vital first steps towards its sustainable use and conservation (Bartley and Welcomme, 1996). Although the number of farmed species reported to FAO is increasing, there is a vast amount of information on genetically differentiated strains, races, varieties and genetically improved species that is not well reported. Such information may not be used effectively to improve aquaculture production. For example, almost none of the hybrids used in aquaculture have been reported as such in national statistics (Bartley et al., in press). In order to assist with documentation, the International Center for Living Aquatic Resources Management, in collaboration with FAO and others, is distributing a relational database on CD-ROM, FishBase, that contains information on many aspects of aquatic biodiversity, including introduced species, fish health, distribution maps, strain registry, genetics and aquaculture (Froese and Pauly, 1996).

A small percentage of aquaculture production now comes from genetically improved species (Gjedrem, 1997). (This refers to directed genetic improvement and not simply to the

domestication process). Therefore, there is tremendous scope to increase productivity by applying techniques of genetic improvement, such as selective breeding, chromosome manipulation, hybridization, production of mono-sex groups, and gene transfer.

Genetic improvement programmes have been successful at increasing production; for example Atlantic salmon in Norway, tilapia in the Philippines, catfish in the southern USA and Thailand, and oysters in North America (Dunham, 1995; Gjedrem, 1997). There is increasing interest in the creation of selective breeding programmes for marine shrimp, tilapia, common carp, and rohu in Asia and Africa (Gupta and Acosta, 1996). Previous work focused on salmonids and inland species, but genetic principles are being applied to marine species more and more as indicated by the increasing number of publications on marine aquaculture genetics listed in the Aquatic Sciences and Fisheries Abstracts (Figure 2.3.2). At several recent meetings in the Mediterranean region, selective breeding of marine fishes, such as sea bass and sea bream, has been identified as a top priority (TECAM, in press).

Figure 2.3.2. Numbers of publications on genetics and marine aquaculture, 1979-1994 (from ASFA)



Selective breeding programmes represent a long-term genetic improvement strategy and are the best means to use fully the genetic resources of aquatic species. However, short-term strategies are also being applied for immediate increase in production. Hybridization between cachama (*Colossoma macropomum)* and morocoto (*Piaractus brachypoma)* accounts for perhaps 80% of the aquaculture of these species in Venezuela. Manipulation of the sex of tilapia broodstock through hormone-induced sex reversal and subsequent breeding can be used to produce predominately male tilapia which then allows tilapia breeders to take advantage of the better growth rates of male tilapia and reduces unwanted reproduction. This technology is being developed and tested in the Philippines as part of a Department for International Development (UK) project with Central Luzon State University (Mair et al., 1995) for commercial application.

Another technique receiving current attention is the transfer of genes between species, or the addition of copies of a species' own gene to improve production. Transgenic common carp, catfish, coho salmon and tilapia have been produced and are being tested for commercial use. Transgenic Atlantic salmon are now being marketed to the industry (Entis, 1997). These transgenic fish demonstrate increased growth and have the potential to increase aquaculture production substantially.

However, there are numerous concerns that must be overcome before full commercial application. Testing of transgenic salmon in Scotland was opposed by several public groups. Expressed concerns were that: i)transgenic fishes may escape into the wild and disrupt natural populations; ii) the "transgene" could be passed on to wild relatives; iii) consumers would not accept genetically modified organisms; iv) the transgene could cause human health problems

if it produced an allergic response where no response was produced by the non-transgenic organism; v) animal welfare may be compromised by the addition of the transgene; and vi) genetic engineering is morally and ethically wrong. In response to these concerns, many researchers and developers are abiding by performance standards such as those produced by the US Department of Agriculture (ABRAC, 1995), and by international agreements, such as the Convention on Biological Diversity and the FAO Code of Conduct for Responsible Fisheries.

The Convention on Biological Diversity has recently designated aquaculture, especially coastal aquaculture, and agrobiodiversity, which includes biological diversity and genetic resources used in or of potential use to aquaculture, as priority areas for action. These international mechanisms acknowledge the value of genetic diversity to both natural ecosystems and aquaculture production systems. Nearly all genetics technologies and breeding programmes rely on genetic diversity as the raw material for improving farmed species. Technical guidelines have been produced to help implement the section of the FAO Code of Conduct for Responsible Fisheries that deals with aquaculture and the use and protection of aquatic biological diversity.

Many genetic techniques have been refined to a point where they are becoming practical for commercial aquaculture and are now being combined to improve production and to address biosafety concerns. For example, transgenic Atlantic salmon are made triploid to reduce the chance of them breeding if they escape. (Entis, 1997). Hybrid Pacific salmon do not perform well in culture, but hybridization combined with triploidization has been shown to provide better sterility, improved growth, and better disease resistance for many species (see general review in Bartley, in press).

Modern molecular techniques now allow analysis of an organism's DNA, such that family relationships and pedigrees can often be established and the genetic stock structure of natural populations can be determined. The use of DNA probes, specifically micro-satellite DNA probes, to identify families and establish pedigrees of farmed animals may greatly facilitate selective breeding programmes where physical tagging is impractical. Micro-satellite probes are being used to map the genomes of commercially important aquaculture species such as Atlantic salmon, carp, catfish, rainbow trout, brown trout, and oysters (e.g. Danzmann et al., 1997; Lie et al., 1997). The mapping effort, which involves collaborative research among several laboratories, countries, and the European Union, will also help identify genetic markers for traits that are of interest to aquaculture. DNA probes are also being used to identify minute quantities of such pathogens as shrimp viruses, thus helping to ensure that an organism is free of a specific pathogen (Wongteerasupaya et al., 1996; see also Section 2.2 *Fish Health and Quarantine*). Most of this work is in the research and development phase at present, but may provide benefits to the industry and to managers of natural aquatic populations in the near future.

Aquaculture is a rapidly growing sector with production steadily increasing at about 10% per year (see Section 1.1 *Status of Global Production and Production Trends*). However, the price of aquaculture products decreases as markets become satiated. For example, the 1995 value per tonne of production from Norway, which is primarily Atlantic salmon, was 29% lower than the 1984 value (Figure 2.3.3). When these figures are adjusted for inflation, the decrease in price is even greater. Genetic improvement programmes were initially developed to increase production. Now one goal of genetic improvement programmes is to increase the value of the farmed product. Additional characters such as flesh quality, body shape and

colouration, that are related to the economic quality of the product are being incorporated into genetic improvement programmes. A selective breeding project on red tilapia in Venezuela will try to improve skin colouration because of the higher market value of red tilapia (FAO unpublished report); the hybrid between the Thai and African catfish is popular because of its flesh quality.

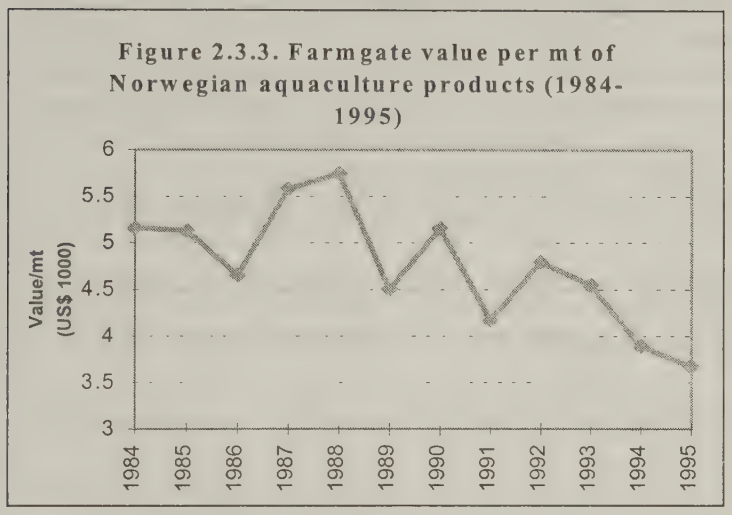


Figure 2.3.3. Farmgate value per mt of Norwegian aquaculture products (1984-1995)

There are still controversial issues that must be addressed in relation to biological diversity in aquaculture, such as the use of introduced species and genetically improved species. Genetic changes in aquaculture species as a result of selective breeding,hybridization, chromosome manipulation, and gene transfer complicate the regulatory structure meant to control the use and movement of such organisms and even the definition of the terms *alien*, *exotic*, and *species* (Pullin and Bartley, 1996). There is a trend toward more regulatory oversight and restrictions on the use of transgenic organisms because this technology is perceived as having a greater risk than other forms of genetic improvement (see above). Although certain technologies, such as gene transfer, may have more uncertainty associated with their use, it is the product of the technology that should be evaluated as to its risk and not the technology per se; that is, the change in an organism's phenotype and not the method used to impart that change should be examined (Pullin and Bartley, 1996). Uncertainties must be addressed through extensive testing, and evaluation and a precautionary approach should be adopted as part of the regulatory oversight. Codes of practice and guidelines for the responsible use of introduced species and genetically modified organisms (e.g. Bartley et al., 1996) and for the application of the precautionary approach to species introductions (FAO, 1996) have been produced to assist in this area.

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2.4 Environment and Sustainability

Barg, U. and M.J. Phillips[1]

Environmental interactions

Aquaculture, like many other farming activities, is dependent upon the use of natural resources such as water, land, seed and feed. It is essentially the use of these resources by aquaculturists as well as their access to appropriate quantity and quality of these resources that determines the nature and scale of environmental interactions. The major environmental interactions of aquaculture have already been reviewed in the literature (e.g. Chua et al., 1989; GESAMP, 1991; Barg, 1992; Pullin, 1993; FAO/NACA, 1995; Phillips, 1995a, 1995b; Rosenthal, 1997), and can be summarized in general terms as shown in Box 2.4.1.

Box 2.4.1. General overview of potential environmental interactions of aquaculture (adapted from Phillips and Macintosh, 1997, and Barg et al., 1997a)[2]

→ Impacts *of* the external environmental *on* aquaculture may be positive or negative. Nutrient enrichment of water bodies may provide nutrients beneficial to aquaculture production in some extensive culture systems (e.g. seaweeds, molluscs). However, excessive loadings with urban and industrial wastes can have severe consequences for aquaculture operations, particularly shellfish culture, when exposed to contamination with toxic pollutants, pathogens and phycotoxins. With increasing aquatic pollution and physical degradation of aquatic habitats by other developments, aquaculturists can face risks of mass mortalities of farmed stock, disease outbreaks, product contamination and reduced availability of wild seed or broodstock. Such impacts are in addition to the adverse effects on composition, abundance and distribution of wild fish populations, which affect capture fisheries. Unlike capture fisheries, aquaculture at least offers opportunities to adapt farming systems and management practices to optimize aquatic food production under sometimes sub-optimal environmental conditions.

→ Impacts *of* aquaculture *on* the environment. As recognized in UNCED's Agenda 21, many types of aquaculture can contribute positively to environmental improvement. Recycling of nutrients and organic matter through integrated farming systems is long recognized as being environmentally sound. Recent developments in Integrated Pest Management have shown how rice-fish culture can help farmers reduce use of environmentally damaging pesticides. Waste-water-fed freshwater aquaculture and coastal mollusc and seaweed farming can be used to recover excess nutrients, thereby reducing risks of eutrophication, etc. In programmes for the restoration and recovery of endangered fish species and stocks, hatcheries and culture systems have been used to provide a temporary sanctuary and to increase numbers of individuals for re-introduction into the wild. Negative impacts have been associated mainly with high-input, high-output intensive systems (e.g. culture of salmonids in raceways and cages), the effects of which can include nutrient and organic enrichment of recipient waters resulting in build-up of anoxic sediments, changes in benthic communities and the eutrophication of lakes. Large-scale shrimp culture in some areas has resulted in degradation of wetlands, localized water pollution and salination problems. Misapplication of chemicals, collection of seed from the wild, introduction of exotic species and overuse of fishery resources as feed inputs, has also raised concern in some locations. Mollusc culture has resulted in local anoxia of bottom sediments and increased siltation.

→ Impacts *of* aquaculture *on* aquaculture have been shown to be acute in intensive cage culture and shrimp culture, in which problems of self-pollution and transmission of diseases have occurred in areas where the high density of farms requires the use of water contaminated by neighbouring installations, with significant losses of farmed stocks and financial returns.

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[1] Network of Aquaculture Centres in Asia-Pacific (NACA)

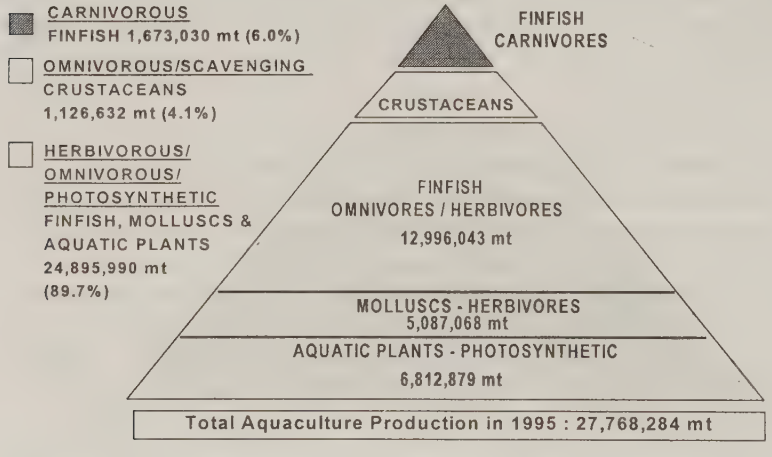
[2] Box 2.4.1 only contains a generalized summary of potential interactions. Magnitude and effects of such interactions are highly site-specific and would require to be ascertained at any given location.

Diversity in aquaculture

Aquaculture has often been viewed as a single activity, but nowadays it is clear that it represents the aquatic counterpart of all terrestrial agriculture under the one name. In fact, many aspects of environmental sustainability are common to both aquaculture and agriculture, and there is much scope for benefiting from experiences made and lessons learned in other food-producing sectors (FAO 1993; FAO/AGLW, 1995; Ongley, 1996; De Haan et al., 1997; De Wit et al., 1997; FAO/UNDP/UNEP/World Bank, 1997; Mearns, 1997; Steinfeld et al., 1997a, 1997b; Upton, 1997). Such a broadened view is increasingly facilitating a more detailed consideration of technological, economic, social, and environmental issues as well as of institutional and legal factors governing aquaculture development. As with agriculture, in aquaculture there is significant diversity in species and farming systems, and in the farmers themselves (Barg et al., 1997a).

Aquatic organisms under culture include a wide variety of taxa and species, and their specific biological characteristics require diverse farming systems within different environments. For example, there are major differences in culture practice and related requirements to provide nutrients, depending on feeding behaviour of the species cultured. Figure 2.4.1 shows the relative contributions of major species groups to global aquaculture production, according to their natural feeding habits.

Figure 2.4.1. Aquaculture production pyramid by major species class and feeding habit in 1995 (pyramid excludes 66,676 mt of miscellaneous aquatic animals; from A. Tacon, pers. com.)



Farming systems are very different as to the level of control and input of resources by the aquaculturist. Significant diversity in the various farming systems can be found with regard to the intensity of use of resources, such as land, water, seed, feed and fertilizer inputs. Most global production is based predominantly on semi-intensive and extensive systems, and on culture-based fisheries, producing affordable finfish for domestic rural markets and subsistence (Tacon et al., 1995). Intensive systems often produce moderate- to high-value species for export or domestic urban markets. However, shrimp, usually grown as a cash crop, can be reared in either extensive, semi-intensive or intensive systems. It is important that the diversity of farming practices and resource uses in aquaculture is recognized and addressed, to help identify feasible and effective management solutions to environmental interactions in aquaculture.

Significant differences exist not only between farming approaches and resource-use patterns, but also between the farmers themselves, and the needs for food security and rural development (Barg et al., 1997a). Nowadays, it is increasingly recognized that environmental interactions of aquaculture should be viewed and resolved within a wider environmental and political context, with due account of the social and economic circumstances in which aquaculture is taking place. Generally, the farming approach employed by aquaculturists in developing countries (in

particular in LIFDCs) has been targeted more toward *management for survival* (Zweig, 1985) whereas the farming approach used in developed countries has been targeted more toward *management for profit* (Tacon, 1996). Traditional aquaculture in many developing countries of the South (Pillay, 1996; see also Pillay, 1997), evolved as small-scale peasant enterprises to suit rural economies. Major characteristics of such aquaculture include (i) family ownership, (ii) polyculture, (iii) integration with crop and animal farming activities, (iv) waste recycling and beneficial use of farm wastes, (v) diversification of food production and spreading of farmers' risks among different commodities, (vi) provision of off-season work for farmers and wage-earners, and (vii) a general means of improving nutrition and incomes. Table 2.4.1 gives a general overview of some major differences, presented as two extremes of a continuous spectrum, in present aquaculture farming practices.

Table 2.4.1. Some major differences in present aquaculture farming practices

Benefit	Survival; subsistence activity	Profit; entrepreneurial activity
Ownership	Family/community	Owners/investors
Culture type	Usually polyculture	Usually monoculture
Integration	Usually integrated into rural farming activities	Separated from other activities, mainly dedicated, stand-alone farms
Waste use/management	Re-used, recycled within farm	Discharged/treated/recirculated
Diversification/specialization	Diversification of product and risk	Concentration of product and risk
Labour	Family/community	Wage earners
Inputs	Low inputs, low cost, available on-farm or locally	High inputs, high cost, available from specialized manufacturers
Output	Food and household income	Profit and dividends

Global awareness

During the last decade, issues such as sustainable development, environmental interactions and long-term sustainability of aquaculture received increasing attention at local, national and international levels (e.g. Chamberlain and Rosenthal, 1995; Reinertsen and Haaland, 1995; Bardach, 1997). Special attention is also given to these issues as relevant to developing countries (Pullin, 1993; FAO/NACA, 1995; Bagarinao and Flores, 1995; ADB/NACA, 1996; NACA, 1996; Nambiar and Singh, 1997). The need to address environmental interactions and sustainability issues for the benefit of sustainable aquaculture development has been reiterated at several global intergovernmental conferences, including the World Food Summit (WFS, 1996), the International Conference on the Sustainable Contribution of Fisheries to Food Security (FAO/Japan, 1995), and the FAO Ministerial Conference on Fisheries in 1995 (FAO Ministerial Conference, 1995). Awareness of the major beneficial and adverse environmental interactions of aquaculture is also reflected in UNCED Agenda 21, Chapters 14, 17 and 18. Following the 1992 Cancún Conference on Responsible Fishing, FAO was requested by its member countries to draft an international Code of Conduct for Responsible Fisheries. The Code was adopted by FAO Member States during the 28th FAO Conference in 1995 (FAO, 1995). The Code's Article 9 on Aquaculture Development contains provisions relating to aquaculture, including culture-based fisheries, and their responsible development in areas of national jurisdiction and within transboundary aquatic ecosystems, to conservation of genetic diversity and ecosystems, and to responsible practices at the production level. Presently, many government authorities and institutions, regional organizations, non-governmental organizations, and private sector associations refer to the principles in the Code when addressing issues of environmental sustainability in aquaculture and fisheries.

Creating an "enabling environment" for sustainable aquaculture development

There appears to be a tendency in the more recent debate on environmental sustainability of aquaculture to neglect the actual and potential adverse environmental effects on resources used in aquaculture, in particular, water, seed and farmed or enhanced stock. Adverse effects of increasing aquatic pollution and habitat degradation on culture-based fisheries, as well as on aquaculture practices and production and the related consequences of such effects on supply of fish as an affordable food commodity, appear to be equally relevant in the ongoing discussion. The current debate is primarily focusing on environmental sustainability of salmonid and shrimp culture, which apparently is leading to attempts to control such types of coastal aquaculture. Much less attention is being given to the need to support and develop sustainable inland culture systems producing food affordable to poor consumers (Bailey and Skladany, 1991; Bailey, 1997).

Given the diversity in aquaculture and the sometimes different perceptions of "sustainability", more balanced and informed approaches are required to address developmental and environmental issues at any given location (FAO Fisheries Department, 1997). While it is well recognized that certain environmental issues in aquaculture need to be addressed and/or resolved, it is equally important to identify those solutions that are viable in the wider context of poverty alleviation and the need to ensure sustained supply of food, particularly in areas where resource-poor segments of rural and urban populations are facing food security problems.

Most aquaculturists, like many of their counterparts in agriculture, continue to attempt to solve problems on their farms while struggling with such constraints as inadequate access to resources, natural and financial, insufficient institutional and legal support, or unavailability of appropriate information (Barg et al., 1997a). A key challenge here is to enable aquaculturists to overcome such problems, with a view to improving farm management and, where necessary, adopting more environmentally sound farming practices. In addition, more opportunities should be given to aquaculture farmers to voice their interests and concerns within existing institutional frameworks, in order to increase their involvement in decision making regarding environmental issues and multiple uses of resources. This may be achieved, for example, through consultations with farmers and their regular participation in public fora (government authorities, research institutions, etc.), possibly supported by the establishment of specific farmers' associations. Further, there are rural development options that offer promise of reducing rural poverty and raising agricultural productivity, while minimizing damage to the environment, such as: (i) improving household health and nutrition by working with women; (ii) tapping unused local knowledge; (iii) giving smallholders access to services, knowledge, and technology; (iv) better managing of common-property resources; and (v) giving rural people a voice in the formulation and implementation of development programmes (World Bank, 1996; see also World Bank, 1997). Such strategic options in many cases may well also apply to aquaculture, and will certainly prove instrumental in ensuring that many aquaculture practices develop in an environmentally sustainable way.

The Code of Conduct for Responsible Fisheries, in its Article on Aquaculture Development, also recognizes the opportunities of enhancing participation of aquaculturists and rural communities in the promotion of responsible aquaculture management practices (FAO Fisheries Department, 1997). However, when negotiating or assigning responsibilities for sustainable aquaculture development in local areas, obligations do not rest only with aquaculturists and their communities. Responsibilities beyond the farm level need to be shared by many players. It is increasingly being recognized that, providing an "enabling environment" for sustainable

development in aquaculture, is the responsibility of governments and their institutions, the media, financial institutions, associations and non-governmental organizations, as well as of social and natural scientists, manufacturers and suppliers of inputs, processors and traders of aquaculture products. Collaboration for sustainable aquaculture development will need to recognize the diversity of aquaculture practices as well as the diversity of the political, social, economic and environmental conditions in which they are or will be taking place (FAO Fisheries Department, 1997).

There is also considerable scope in encouraging collaboration among aquaculture producers, with a view to promoting environmentally sustainable production practices. Major benefits to farmers can be derived, for example, from association in producer organizations, and from the development and adoption of self-regulatory codes of practice in aquaculture (Box 2.4.2).

Box 2.4.2. Potential benefits of association and self-regulation (adapted from Phillips, 1997; FAO Fisheries Department, 1997; Barg et al., 1997a).

→ *Public image:* Public image can be enhanced through adherence to established and agreed norms and adequate self-regulation.

→ *Defending interests:* Aquaculturists are in a better position to defend their interests, and to negotiate for rights and privileges against competing interests.

→ *Greater common understanding:* Greater common understanding and agreement on specific measures that can be implemented to ensure sustainable development of aquaculture;

→ *Clarification of responsibilities:* Roles and responsibilities of concerned agencies and interest groups can be properly identified and negotiated.

→ *Improved management and sustainability:* Codes of practices themselves will not lead to improved management and sustainability. However, adoption of improved practices, for example through widespread dissemination of relevant information and training, could help their implementation. Additionally, as part of integrated area management, responsible aquaculture acknowledges its interaction with other sectors in the conservation and efficient use of resources, and therefore can request that those sectors do not compromise the availability of resources in adequate quantity and quality required for aquaculture (and fisheries).

Nowadays, there are numerous initiatives at international and national levels to address issues of environmental sustainability in aquaculture. A number of these initiatives are specifically aiming at providing assistance to developing countries. For example, a regional study on aquaculture sustainability and the environment, supported by the Asian Development Bank and implemented by the Network of Aquaculture Centres in Asia-Pacific (NACA), provided significant insight on environmental performance of Asian aquaculture farms, and resulted in the formulation of a regional Aquaculture Sustainability Action Plan (ADB/NACA, 1996). Efforts are under way on a global scale through FAO to launch an Inter-regional Programme of Assistance for the Implementation of the Code of Conduct for Responsible Fisheries, with components designed to help governments in formulation and application of policy and regulatory measures related to aquaculture development. NACA and FAO have been collaborating on the development of a code of responsible practice for sustainable shrimp culture, and an upcoming FAO consultation is expected to generate guidance on the formulation of policies for sustainable shrimp culture. Other efforts aim at the development of technical guidelines on specific aspects, for example, feed manufacturing, use of introduced species, quarantine and health certification for responsible movement of aquatic organisms (FAO Fisheries Department, 1997). International expert meetings have been held, for example, to review the use of chemicals in aquaculture (GESAMP, 1997;

SEAFDEC/FAO/CIDA, in press), and to formulate guidance documentation on monitoring of ecological effects from coastal aquaculture wastes (GESAMP, 1996).

Environmentally sustainable increases in food supplies from aquaculture

In 1996, the World Food Summit agreed "to promote the development of environmentally sound and sustainable aquaculture well integrated into rural, agricultural and coastal development" (WFS, 1996). The challenges for aquaculture to continue its impressive growth and contribution to food supplies are in many ways related to its environmental interactions. Growing awareness of environmental interactions of aquaculture is leading planners, decision makers, investors and aquaculturists to view aquaculture developments within a wider context of resource use, both at local as well as larger ecosystem levels. It is generally recognized that aquaculture will face competition for finite resources, particularly freshwater and, in some areas, land. It is less widely recognized that aquaculture--properly integrated into agricultural farming systems and coastal land use--can add value to both water and land resources. However, pressure on resources continues to increase due to population growth, coupled with unequal distribution of food, other goods and services, and increasing degradation of aquatic environments (e.g. Chua et al., 1989; Dudgeon, 1992; Petr and Morris, 1995; Muir, 1995; Barg et al., 1997b). Regulatory measures to reduce environmental degradation by major offenders are sometimes lacking or not enforced. In contrast, aquaculture, a relatively minor offender, is often not recognized as a legitimate resource user, whether by government authorities, other resource users, major polluters, or the public in general. This has produced a climate under which there is little protection of the aquaculturists' needs for adequate quality and quantity of resources (Van Houtte, 1994; FAO/NACA, 1995), and may increase the investment risks in the sector. Long-term consequences of uncoordinated resource use in river basins or coastal areas are sometimes ignored or neglected, particularly with regard to the social and economic value of goods and services provided by aquatic ecosystems, their genetic resources and biodiversity. Neglecting these considerations may affect not only the sustainability of aquaculture and culture-based fisheries, but also the sustainability of many inland and coastal fisheries.

The pressure on aquaculture to use resources more efficiently, to increase competitiveness and to respond to market forces is resulting in some areas in trends toward intensification of aquaculture production. These are associated with more sophisticated farm management, shift to monoculture of high-value species, and the targeting of affluent consumers. There is an increased risk that such trends to intensification will increase environmental impact and economic losses due to disease if inappropriate planning and management of such farming systems and, in particular, the inefficient use of resources and inputs such as equipment and chemicals, are not avoided (Barg et al., 1997a).

However, more intensive production systems can help reduce environmental and resource-use problems. For example, extensive systems require large areas (space) of land or water, potentially contributing to degradation of habitat in some areas. More intensive systems require less area and can be more efficient in terms of resource use and production. A good example is shrimp farming: the majority of shrimp farms are extensive or semi-intensive, and the highly publicized problems of wetland degradation are often associated with extensive systems. Intensive systems obviously may create pollution problems due to high inputs and high waste output, but this greatly depends on very site-specific characteristics, and, in particular, of the assimilative or environmental capacity of the recipient water body. In general, effectiveness of measures and efficiency in management at the production level may well be very important criteria for consideration when promoting sustainable development of aquaculture.

Politically, food production remains an over-riding priority, and intensification as well as diversification in food production are both avenues which cannot be discarded, at least not generally. The question may be raised, however, if it would not be more appropriate to promote food production in inland rural areas, thereby helping to reverse migration to cities and coastal areas, and to reduce pressures on coastal resources and environments. It has also been suggested that semi-intensive systems may be more environmentally friendly and more socially acceptable, due to their significant potential to use less exogenous supplementary feed inputs, while providing many opportunities of efficiently converting locally available nutrient resources (such as naturally available food organisms, and agricultural by-products and wastes) into production of fish affordable to a wide range of consumers in rural communities and urban centres (Tacon et al., 1995; Bailey, 1997). In addition, as suggested by Bailey (1997), such systems often are within the reach of a wider range of resource-poor producers, being significantly less dependent on capital investment, and are therefore more likely to contribute to local economies and to enhance the ability of local communities to maintain social and economic viability.

In the long term, there may be limits in some areas to increases of supplies of affordable food from certain types of aquaculture, resulting from resource constraints or adverse environmental interactions. There appear to be significant opportunities for widening development perspectives toward alternative, more sustainable, increases in food supplies, away from too narrow a focus on promotion of sophisticated capital-intensive aquaculture production systems. There is considerable scope for much greater integration between fisheries, aquaculture and water resource management. Roberts and Muir (1995) suggest that where social and other conditions permit the management and regulation of fisheries, or where existing natural resources are threatened by other activities, aquaculture techniques such as broodstock selection and hatchery production may become more important in supporting or enhancing fisheries (see also Coates, 1995; Muir, 1995; Welcomme, 1997a).

There is increasing recognition that there are many water bodies, man-made and natural, where there is potential for significant production increases and associated benefits via fisheries enhancements (FAO/DFID, 1997). "Biomanipulation", using aquaculture-based knowledge or techniques to enhance productivity of such water bodies may widen opportunities for lower-cost food production. There is a considerable range of management practices intermediate between aquaculture and capture fisheries (including stocking, introduction of new species, fertilization, environmental engineering, etc.; see Welcomme, 1997a), which may benefit subsistence fisheries in less developed rural areas, but also commercial and, increasingly importantly, recreational fisheries. These techniques may well provide additional means for managing aquatic environments and resources, for the purposes of enhanced food production, environmental rehabilitation and re-development, particularly if well integrated into sustainable water resource management schemes, including those designed for irrigation and hydropower generation (see also Goodland, 1996; Barg et al., 1997b; Biswas, 1997). However, the financial and social need for fishery enhancement measures should be established, and impacts on natural systems should be monitored as closely as possible (Welcomme, 1997b; see also FAO/DFID, 1997).

For future increases in aquatic food supplies from inland and coastal environments to be environmentally sustainable, it appears preferable, if not essential, that aquaculture (as well as wild and enhanced fisheries) is developed with due account of the linkages between resource use at the production level and the environmental goods and services available in upstream, downstream and coastal environments (see e.g. Muir, 1996). Approaches of integrated

assessment and management of resources available within larger ecosystems such as river or lake basins and coastal zones are increasingly being suggested for application to aquaculture developments, in both developed and developing countries (Barg, 1992; Kapetsky, 1994; Kapetsky and Travaglia, 1995; Rosenthal and Burbridge, 1995; Muir, 1996; Barg et al., 1997b; Chua, 1997; ICES, 1997, Kapetsky and Nath, 1997; Phillips, 1997; Rosenthal, 1997; FAO, in press). An upcoming GESAMP working group meeting is expected to generate more detailed analysis of experiences on the integration of aquaculture into coastal management. Given that there have been cases of serious disagreement and severe social contest over environmental issues and/or access to resources shared by aquaculturists and other resource users, it is increasingly being recognized that such conflicts can and should be addressed, for example, through conflict resolution techniques (e.g. facilitated dialogues, mediation, arbitration, etc.) and enhanced involvement of local stakeholders in resource allocation and management decisions (see e.g. Townsley, 1996).

Defining sustainability of aquaculture development

It appears that there is an urgent need to overcome the extremes of current experiences in aquaculture development, which were characterized above as *management for survival* and *management for profit*, and to provide practical and conceptual solutions that combine their positive features for the benefit of sustainable food supplies from aquaculture. Sustainability issues in aquaculture are becoming increasingly important and the extent of the problems can be such that they can no longer be ignored (Beveridge et al., 1997). Greater attention will need to be given in aquaculture to *management for sustainability* (Phillips, 1997), and a systems approach has been suggested by Muir (1996) to address these problems. However, not only the current debate but also many policy and management decisions on sustainability in aquaculture often are constrained by a lack of agreement on, or clear understanding of, the meaning and practical applications of the sustainability concept. While there are many different definitions of sustainable development, some authors have emphasized that bringing such definitions into a more practical development framework involves consideration of technical, social, environmental, economic and institutional issues, as well as inter- and intra-generational equity (e.g. Muir, 1996). In this context, a recent perspective on the concept of sustainability is given, for example, by Goodland and Daly (1996) who distinguish social sustainability and economic sustainability from environmental sustainability.

Because sustainability is a complex issue involving a number of considerations related to the ecosystem and society, a system of indicators is needed, the scope of which should cover both the resources to be used sustainably and the goods and services obtained from the system, as well as relevant societal parameters (Garcia, 1997; Garcia and Grainger, 1997). Further development of sustainability criteria and indicators which are practical and which reflect trends in aquaculture development as well as changes in aquaculture practice would be a step forward in helping to guide management and policy decisions in aquaculture. Such definitions may provide a basis from which management options might be evolved in aquaculture projects as well as potentially important 'targets' in developing aquaculture projects. The development of indicators for sustainable development of fisheries is already in progress (Garcia, 1997; Staples, 1997). The FAO Fisheries Department is currently preparing for a technical consultation on indicators for sustainable development of aquaculture, including criteria for use and allocation of resources for aquaculture, to be held in 1999 in collaboration with interested partners.

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2.5 Safety of Food Products from Aquaculture

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As aquaculture assumes an expanding role in meeting consumer demand for fishery products, it is only natural that the quality and safety of its products come under the scrutiny of national and international organizations responsible for food safety. The issue of safety and quality is of concern to all consumers in both producing and importing countries, and hints of potential hazard may be sufficient, under some circumstances, to create economic damage. Recent concern about assessment and control of food safety and quality in aquaculture is both timely and important, as is the development of an information base and other tools to enable objective assessment of hazards and risks.

International initiatives related to food safety

The 1995 FAO Conference adopted the Code of Conduct for Responsible Fisheries which calls for, inter alia, food safety and quality of aquaculture products. The Code's Article 9 *Aquaculture Development*, and in particular its provisions for *Responsible Aquaculture at the Production Level*, address the need for safe and effective use of feeds, feed additives, fertilizers, manure, chemo-therapeutants and other chemicals.

The rules that govern international trade in food were agreed upon during the Uruguay-Round on Multilateral Trade Negotiations and apply to all members of the World Trade Organization (WTO). With regard to food safety, these rules are set out in the *Agreement on Sanitary and Phytosanitary Measures* (SPS Agreement). According to the SPS Agreement, WTO members have the right to take legitimate measures to protect the life and health of their people from hazards in food, but these measures may not be unjustifiably trade restrictive. Also, these measures have to be based on risk assessment, taking into consideration the risk assessment techniques developed by relevant international organizations. In regard to food safety, the relevant international organization is the FAO/WHO Codex Alimentarius Commission (CAC)[2]. In order to facilitate and harmonize risk assessment, the CAC has adopted a number of definitions in relation to risk analysis. In this context, it is particularly important to recognize that a *hazard* is a biological, chemical or physical agent in, or condition of, food, with the potential to cause harm. In contrast, *risk* is an estimate of the probability and severity of adverse health effects in exposed populations, consequential to hazard(s) in food.

Identification of hazards in food and the determination of their relevance for health as well as their control is the function of the science of risk analysis. Risk analysis is an emerging discipline in food control; the methodological basis for assessing, managing and communicating risks associated with food-borne hazards is, at the international level, still in a developing phase.

Within the Codex system, broad issues relating to food safety that are also applicable to products from aquaculture, fall under the general subject committees, such as the Codex Committees on Food Additives and Contaminants, Food Hygiene, Pesticide Residues, and Residues of Veterinary Drugs in Foods. The Codex Committee on Food Hygiene has revised

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[1] FAO Consultant

[2] In regard to animal (including fish) health and disease, the relevant international organization is the International Organization on Epizootics (OIE).

the International Code of Practice on General Principles of Food Hygiene which lays a firm foundation for ensuring food hygiene throughout the food chain, from primary production through to final consumption. It recommends a HACCP-based approach (see below) wherever possible to enhance food safety, and the controls described are internationally recognized as essential to ensure the safety and suitability of food for consumption. In addition, specific food safety issues are covered by the Codex Committee on Fish and Fishery Products, which is preparing the Draft Code of Hygienic Practice for the Products of Aquaculture (FAO, 1996). This draft code is under revision and it is intended to assist those engaged in aquaculture to produce high-quality fish that is safe for human consumption. The Code covers all stages of the aquaculture production cycle, from the selection of a site for establishing a fish farm, to grow out and primary on-farm handling of products.

A number of meetings have been convened as part of the effort to develop risk analysis for food safety at the international level, to synthesize and disseminate information on food safety (including food production from aquaculture), and to address related issues. These have included:

- FAO/WHO Consultation on HACCP: Concept and Application (WHO, 1995a);
- FAO/WHO Expert Consultation on the Application of Risk Analysis to Food Standard Issues (WHO, 1995b);
- FAO/WHO Expert Meeting on Food Safety Risk Management (FAO, 1997);
- FAO Expert Consultation on Animal Feeding and Food Safety (FAO, in press).

Meetings focused exclusively on aquaculture have included the SEAFDEC[3]/FAO/CIDA[4] Expert Meeting on the Use of Chemicals in Aquaculture in Asia (SEAFDEC/FAO/CIDA, in press), the findings of which were discussed by an ad hoc meeting of the GESAMP[5] Working Group on Environmental Impacts of Coastal Aquaculture (GESAMP, 1997); and a Joint FAO/NACA[6]/WHO Study Group on Food Safety Issues Associated with Products from Aquaculture (WHO, in press). The Study Group considered food safety issues associated with farmed finfish and crustaceans, particularly those associated with biological and chemical contamination that may occur during the production of these aquatic products. It considered the quantification of hazards and how to implement measures for control of potential food safety hazards, including current national and international programmes. It also identified knowledge gaps and research needs (WHO, in press).

Safety of food products from aquaculture

Hazards and risks that may adversely affect the health of people are inherent in all human activities. Aquaculture is no exception to this general rule. Unfortunately, whereas 87% of the world production from aquaculture derives from developing countries in the tropics and sub-tropics, most of the literature on hazards and the public health aspects of fish and fishery products deals predominantly with the hazards of marine fish caught or harvested in temperate waters, and processed and marketed in developed countries (Ward, 1989; Liston, 1990; Ahmed, 1991a; Ahmed, 1991b; Gibson, 1992). Information on hazards associated with aquaculture species from warm waters is sparse in comparison (Edwards, 1992; Reilly, 1992;

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[3] Southeast Asian Fisheries Development Center
[4] Canadian International Development Agency
[5] IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on Scientific Aspects of Marine Environmental Protection.
[6] Network of Aquaculture Centres in Asia-Pacific

Buras, 1993). An exhaustive review of the safety of food products from aquaculture is not in the remit of this article. However, some major issues are summarized below.

Food-borne trematode infections, food-borne diseases associated with pathogenic bacteria and viruses, residues of agro-chemicals, veterinary drugs and heavy-metal organic or inorganic contamination have been identified as possible hazards in aquaculture products (Garrett et al., 1997; Reilly et al., 1997). These hazards are usually associated with the aquaculture habitat, the species being farmed, the general condition of the local environment, and cultural habits of food preparation and consumption. Fortunately, one of the several advantages of aquaculture as a source of food fish is that the producer can exert control over the intrinsic quality, including the safety, of the product. Though this aspect of aquaculture may not have received adequate attention until very recently, many of the identified potential hazards at the production level can be controlled by good fish farm management practices, and consumer education regarding such risks as eating raw or partially cooked products that may contain parasites. The introduction of safety management systems in fish farm management may add to the cost of aquatic products. However, the added cost will probably be small and there could be, in fact, a cost saving--the management controls and improved quality assurance can result in improved efficiency of production and reduction of cost. Furthermore, the cost of placing unsafe food products on the market can be detrimental to the industry as well as to national economies in terms of product rejection in international trade and industry reputation (Reilly et al., 1997).

The principal biological agents that cause food-borne disease are bacteria, viruses, parasites and to a lesser extent, moulds. Parasite-related food safety concerns in aquaculture are limited to a few helminth species, and the hazards are largely focused on communities where consumption of raw or inadequately cooked fish is a cultural habit (WHO, 1995c; WHO, in press). The main human diseases caused by fish-borne parasites are trematodiasis, cestodiasis, and nematodiasis. Trematodes are by far the most important food safety hazard linked with fish and fishery products. These parasites can cause illnesses ranging from debilitation to cancers and death. The most important trematodes, so far as numbers of people affected is concerned, are species of the genera *Clonorchis*, *Opisthorchis* and *Paragonimus*. WHO (1995) estimates that tens of millions of people are affected by fish-borne trematodes, though not necessarily of aquaculture origin. There is a lack of specific and quantitative information about the extent of the hazard in farmed fish, but the little information we have shows that parasites are found in farmed fish, and there is some, though scanty, epidemiological evidence of transmission of trematode parasites from farmed fish. Since a large volume of global production of farmed freshwater fish is produced in areas of the world where these parasites are endemic in the natural fish population, and are the cause of considerable illness to humans, it can be assumed from a precautionary viewpoint that freshwater fish farmed in these areas pose a potential hazard, even if the risk cannot be objectively assessed at this time.

Molluscs present a higher risk of causing human illness from bacterial or viral pathogens than do crustaceans and finfish. The greatest number of seafood-associated illnesses are from consumption of raw molluscs harvested in waters contaminated with raw or poorly treated human sewage (Ahmed, 1991a; Hackney and Pierson, 1994). However, there is no indication that mollusc farming practices per se increase the risk over that of bivalves harvested from wild populations from the same waters (Hackney and Pierson, 1994). Human viral diseases caused by the consumption of finfish and crustaceans appear to present a low risk, while viruses causing disease in fish are not pathogenic to man.

The level of contamination of aquaculture products by pathogenic bacteria will depend on the environment and the bacteriological quality of the water where the fish is cultured. There are two broad groups of bacteria of public health significance that will contaminate products of aquaculture: those naturally present in the environment--indigenous microflora (e.g. *Aeromonas hydrophila*, *Clostridium botulinum*, *Vibrio parahaemolyticus*, *Vibrio cholerae*, *Vibrio vulnificus*, and *Listeria monocytogenesi*); and those introduced through environmental contamination by domestic animal excreta and/or human wastes--non-indigenous microflora (e.g. *Enterobacteriacae* such as *Salmonella* spp., *Shigella* spp., and *Escherichia coli*) (Huss, 1994).

It should be noted that non-indigenous bacteria of faecal origin can be introduced into aquaculture ponds via unavoidable contamination by birds and terrestrial animals associated with farm waters, in systems in which manures are not used for nutritional input. There is a rapid die-off of enteric organisms and viruses in well managed ponds (Edwards, 1992; Buras, 1993), but significant numbers of organisms remain on the skin and in the guts of fish and can pose a health risk to consumers. Therefore, regulatory authorities should not immediately assume that raw aquaculture products, particularly raw frozen shrimp, containing *Salmonella* are due to poor sanitary practices. Adequate cooking (i.e. the thermal centre of the product should reach 70°C) before consumption will eliminate the risk. Epidemiological evidence suggests that a far higher level of consumer risk from these bacteria is associated with eating other products of animal origin, such as poultry and red meats, than with eating finfish and crustaceans from culture or capture fisheries (WHO, in press).

Cholera (*Vibrio cholerae)* and gastroenteritis (e.g. *V. parahaemolyticus*) have been associated with consumption of raw fish and shellfish from production sites receiving contaminated human waste, but commercially traded seafoods are unimportant in the epidemiology of cholera. There is also high risk of septicaemia (*V. vulnificus*) from ingestion of contaminated raw bivalves, especially oysters, and contact with contaminated seawater; but the risk from finfish is low (WHO, in press).

Bivalve shellfish can accumulate biotoxins such as PSP (paralytic shellfish poisoning), DSP (diarrhetic shellfish poisoning) and ASP (amnesic shellfish poisoning), and become harmful to consumers; farmed shellfish are as much a risk as are wild populations. The extent of accumulation of these toxins by finfish and crustaceans in aquaculture production facilities is still not clear. Finfish commonly produced through aquaculture will not survive exposure to PSP and therefore do not pose a risk to consumers. At present, there is very little aquaculture production of species that have the potential to be toxic (e.g. tetrodotoxin in puffer fish).

Many chemo-therapeutants are used to treat fish and the environment in which fish are grown, to control diseases and pests. The chemicals used are selected to have low toxicity to fish and they would also have low toxicity to humans. In extensive aquaculture systems, there has not been any significant use of chemotherapy, and in sophisticated, intensive production systems, the use of vaccines, coupled with changes in husbandry practices--lower stocking densities, rotation of sites and fallowing--has reduced the incidence of disease and drastically reduced the use of chemo-therapeutants (predominantly in the case of the salmon farming industry). A steady reduction in use of chemo-therapeutants, through improved husbandry, is possible and in progress in many areas (WHO, in press). While therapeutant residues resulting from aquaculture treatments may not appear to be a significant hazard to humans when considering the extremely small number of cases reported, producers must be alert to the significant public concern created by potential residues (Armstrong, 1997).

There is global concern about the consumption of low levels of antimicrobial residues in aquatic foods and the effects of these residues on human health (Reilly et al., 1997). There are now reports of plasmid-mediated antibiotic resistance among bacteria found in fish farms, and transfer of this resistance to organisms not directly in contact with the antibiotics. The danger is that illnesses in humans caused by antibiotic-resistant organisms derived from aquatic products, or the environment of aquaculture systems, might not respond to medical treatment (Howgate, 1997). This is of special concern in countries where regulations for the use of antimicrobials exist but may not be effectively enforced, and where no regulations exist at all.

There is evidence that antimicrobial-resistant strains of fish pathogens have developed over the time in which antimicrobials have been used to control fish disease (WHO, in press). In general, however, it is difficult to evaluate evidence of antimicrobial resistance because of the different methods used in the published literature. There is little agreement as to how resistance in fish pathogenic bacteria should be defined and no consensus as to how it should be measured. There is need for developing widely accepted standard methodologies (Smith et al., 1994). In addition, since studies are often of a qualitative nature, there is a tendency to report potential risks rather than to assess their importance objectively (Smith et al., 1995).

Where the use of chemo-therapeutants is necessary (i.e. where vaccination is not an option), the approach to avoid major risk to consumers is addressed in the Codex Commission document: proposed Draft Code of Hygienic Practice for the Products of Aquaculture (FAO, 1996).

In general, aquaculture in inland waters carries a greater risk of contamination from agro-chemicals, while aquaculture in estuaries is more susceptible to contamination from industrial pollutants. Two classes of pollutants are of concern with respect to human health: heavy metals and chlorinated hydrocarbons. Unfortunately, there is little information on their levels in cultured fish to allow risk assessment. With regard to heavy metals, methylmercury is of the most concern to human health. In this regard, it is likely that aquaculture products are safer than their wild counterparts, since mercury accumulates with time and aquaculture products, especially crustaceans, are harvested at a young stage. Nevertheless, bearing in mind that aquatic products are major contributors of mercury in humans, there is a clear need for more information about the mercury content of aquaculture products and the influence of aquaculture practices on it.

The chlorinated hydrocarbons of most concern for human health are the chlorinated insecticides and their degradation products, and the polychlorinated benzodioxans and furans. The use of chlorinated pesticides has been phased out in developed countries, but they may still be in use in some developing countries, or have been phased out only recently. PCBs and similar highly chlorinated industrial chemicals have not been manufactured and used to the same extent in developing countries where most freshwater aquaculture is concentrated, although they are distributed in the atmosphere on a global basis. Available information is restricted to levels of these chemicals in wild fish.

The HACCP approach to safety control of aquaculture products

According to modern public health concepts of prevention and control of food-borne diseases, consumer hazards derived from food intake should be considered under a HACCP (hazard analysis critical control point) perspective. The HACCP system is applied from production to

consumption and offers a systematic sequential approach to the control of food-borne hazards, avoiding the many weaknesses inherent in the traditional inspection approach.

The draft Code of Hygienic Practice for the Products of Aquaculture, prepared by FAO, is presently under review by the Codex Committee on Fish and Fishery Products, aiming at including HACCP principles into the document. The new text will give particular attention to biological agents such as bacteria (*Salmonella* spp., *Vibrio* spp.) and parasites (*Clonorchis sinensis*) of human health significance, chemical contaminants (heavy metals, agricultural pesticides, industrial chemicals) and residues of veterinary drugs (antibiotics).

Identification of ways and means to bring about the application of HACCP-based safety control systems to some types of aquaculture systems may pose a major challenge. HACCP requires that the hazards of a product or process be identified, that means of controlling the hazards exist, and that there are procedures for monitoring the effectiveness of the control measures. These conditions do not apply fully to all hazards and all current aquaculture practices (Howgate, 1997). Further, when carrying out an HACCP evaluation of a system, it is necessary to consider, in addition to the hazards, the risks; that is, the probability that the hazards would cause disease in humans (Ozonoff and Longnecker, 1991; Ahmed, 1992; Hathaway, 1993; Rose, 1995). It is not possible to calculate these risks for most of the production from aquaculture because there is little quantitative data on the intensity or extent of the hazards, and little epidemiological data on which to base estimates of the risk (Howgate, 1997).

It may not be difficult to apply the HACCP-based system to large-scale commercial aquaculture ventures. However, in small-scale, subsistence aquaculture systems, where fish are mainly farmed for domestic consumption under minimal inputs, knowledge and assistance, application of an effective HACCP-based system will pose considerable difficulties. Therefore, the design and implementation of HACCP systems should be considered following careful evaluation of the feasibility of applying such a control system to a particular aquaculture system, the risks associated with the systems components and procedures, and the identification of the correct and appropriate critical control points (WHO, in press). The HACCP approach is unique for every product and for every production unit: in each case a detailed study of the fish farming methods, inputs and production conditions is required, and the sequential flow is necessary to identify hazards and the critical control points.

The industry and government in the USA have succeeded in developing comprehensive HACCP plans for selected aquaculture products, i.e. catfish, crawfish and molluscs. A similar approach is being initiated in a few other countries, i.e. Australia, Chile, New Zealand, Norway and Thailand. FAO is carrying out studies on the use of HACCP for the control of fish-borne trematode infections in pond-raised carp in Thailand and Vietnam, in endemic areas affected by clonorchiasis and opisthorchiasis.

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2.6 Development of Regulatory Frameworks

Cullinan[1], C. and A. Van Houtte

Aquaculture is already a significant industry in many countries and, in the face of static landings from capture fisheries, is being called upon to help meet the expected future gap in food fish supplies. Yet, in many countries laws regulating aquaculture are poorly developed and frequently consist of a few articles in a law regulating capture fisheries (an activity very different to aquaculture). However, during the last few years there has been a growing interest in many countries to develop a comprehensive regulatory framework for aquaculture that will protect the industry, the environment, other resource users and the consumer. This is being driven by a variety of factors, including: greater political attention as the economic importance and potential of aquaculture become more apparent; greater awareness that inappropriate laws and institutional arrangements can significantly constrain the development of the sector; evidence of environmental damage and social disruption as a result of the rapid and largely unregulated expansion of shrimp farming; and a growing emphasis on examining production methods as a means of improving the quality and safety of aquaculture products in international trade.

While capture fisheries are generally regulated by a single government department, aquaculture is frequently regulated by many agencies under a variety of laws. This means that developing a comprehensive regulatory framework for aquaculture is often legally and institutionally complex. Typically it involves drafting or amending legislation which addresses a variety of issues such as land use planning and tenure, water quality, fish movement and disease, pharmaceutical use, food quality and public health. It also requires establishing institutional arrangements to ensure co-operation and co-ordination of many different institutions with jurisdiction over natural resources, animal and public health, environment, etc.

International developments

The adoption of the non-binding Code of Conduct for Responsible Fisheries (CCRF) by the 1995 FAO Conference (FAO, 1995), promises to have a significant worldwide influence on the development of regulatory systems for aquaculture in the coming years. Article 9 of the Code deals with aquaculture development and sets out a wide range of relevant principles and criteria. The first principle is that *States should establish, maintain and develop an appropriate legal and administrative framework which facilitates the development of responsible aquaculture*. FAO has also produced technical guidelines for responsible aquaculture development (FAO, 1997), which are intended to provide general advice in support of the implementation of Article 9 of CCRF.

Progress has also been made in the application of the hazard analysis critical control point (HACCP) system to aquaculture and FAO has published general guidance on seafood quality aspects (Huss, 1993). FAO is also currently involved in reviewing the draft Code of Hygienic Practice for the Products of Aquaculture under the auspices of the Codex Alimentarius Committee on Fish and Fishery Products. The Code deals with key hygienic factors involved in all aspects of farming of finfish and crustaceans from location and layout of aquaculture facilities to end-product specifications and HACCP for the products. The Code is advisory in

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nature and is intended to be used as a guideline for preparing national quality standards and fish inspection regulations by countries which do not have fully-developed laws in this area (see also Section 2.5 *Safety of Food Products from Aquaculture*).

In addition, the "Jakarta Mandate" adopted by the second Conference of the Parties to the Convention on Biological Diversity in 1995, provides useful guidance regarding environmental aspects which should be taken into account in developing coastal aquaculture (De Fontaubert et al., 1996; see also Section 2.3 *Biodiversity and Genetics*).

Regional and national developments

The development of aquaculture in Asia continues to be rapid and during 1994 and 1995 several regional workshops dealing with environmental, legal and institutional issues associated with aquaculture were held under the auspices of FAO and/or the Network of Aquaculture Centres in Asia-Pacific (NACA). Recently, FAO published a two-volume compendium on aquaculture and inland fisheries legislation in the Asian region (FAO, 1996) with the assistance of funding from the Norwegian Agency for Development Co-operation.

Although new national laws to regulate aquaculture comprehensively may be desirable in many countries in the region, other options are now being explored because developing and passing new comprehensive legislation is likely to take several years, while the rapid development of the sector has created an urgent need for regulation. These options include the enactment of regulations under existing legislation, and voluntary approaches such as guidelines and codes of practice.

The effectiveness of voluntary codes of practice can be enhanced by creating incentives to encourage compliance or disincentives for non-compliance or failure to join the scheme. In a sense, the environmental and social requirements that must be met for World Bank funding already function in this way. Another example is the policy adopted in 1995 by the National Bank for Agriculture and Rural Development (NABARD) in India (the major source of refinancing for brackishwater prawn farming in the States of Andhra Pradesh and Tamil Nadu), which sets out conditions to be met before NABARD provides agricultural credit to banks for aquaculture developments. For example, projects involving intensive culture or the conversion of non-saline land to brackishwater aquaculture will not be sanctioned, and refinance support will be provided to enable banks to provide additional loans for sedimentation tanks and effluent treatment facilities to meet NABARD requirements (Aquaculture Foundation of India, 1995) Similarly, Malaysia is giving consideration to requiring aquaculture enterprises that are given preferential "pioneer" tax status to adhere to a code in order to retain various tax incentives. There is clearly scope for increasing the use of conditional public and private sector funding to encourage more sustainable aquaculture practices.

Although the integration of aquaculture concerns into resource use and development planning is critical for the development of the sector, this integration is lacking or poor in most countries, probably because aquaculture has developed more recently than other sectors. The Australian State of Tasmania has recently enacted legislation which provides an interesting example of what can be done to address this issue. Under new legislation (notably the Marine Farming Planning Act 1995 and the Living Marine Resources Act 1995), marine farming development plans covering areas, rather than sites, must be prepared, and the law provides for broad community participation in the preparation of the plans. An environmental impact

assessment must also be carried out and a marine farming zone established before leases are granted to marine farms.

Malaysia is currently engaged in a project with the assistance of FAO to develop an integrated regulatory system for aquaculture in the short to medium term without attempting to enact a new comprehensive aquaculture act. This will involve enacting new regulations under the existing Fisheries Act, introducing a voluntary Code of Responsible Aquaculture Practices for inland cage culture and shrimp farming, supported by incentives, and strengthening institutional structures to ensure the ongoing formulation and monitoring of aquaculture policy at federal and state levels.

Many regulatory systems could be improved by including mechanisms which are designed not only to prevent or reduce the risk of environmental harm, but also to help put right any damage which may occur. The Tamil Nadu Aquaculture (Regulation) Act, 1995 not only sets out conditions to improve the siting and management of aquaculture facilities, but also establishes an Eco-restoration Fund, funded partially by deposits from aquaculturists, to be used for remedying environmental damage caused by aquaculture farms. In the European Union (EU), major regulatory developments have been driven, on the one hand, by the growing concern for the quality of the water resources and the consequential need to ensure conservation of and control over the pollution of the aquatic environment[2], and, on the other hand, by the need to develop harmonized standards for fish food products marketed within the EU[3]. The EU currently imposes detailed conditions on the handling, slaughter, inspection, processing, packaging, identification and storage of fishery products[4], and applies stringent controls over the animal health conditions applicable to the marketing of aquaculture animals and products[5].

In many Eastern European countries, the establishment of a framework for aquaculture is a low priority relative to the more urgent challenges of building up coherent legal systems to regulate matters such as land tenure. However, Poland passed a new Fisheries Law in 1996 which provides that a permit from the relevant Maritime Office is required for the conduct of fish culture or stocking activities.

Aquaculture activities in Africa have so far only made a limited contribution to national economies. However, aquaculture legislation is being drafted in Madagascar and Mozambique with the assistance of FAO. A preliminary study of the legal and institutional issues in these countries indicates that the legal framework governing access to land suitable for aquaculture has a profound influence on the development of the sector.

Aquaculture is included in the basic fisheries legislation in most Latin American countries. However, specific reference to aquaculture problems and their solution is included in special legislation in Chile in Decree No. 291, 1985, prescribing the regulations for the control of

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[2] Reference is made to directives prescribing limits for discharges of certain substances into the aquatic environment such as Directive 76/464/EEC (on the discharge of dangerous substances into the aquatic environment) and the various daughter directives made under it; and the EC water quality directives, such as Directive 78/659/EEC (on the quality of freshwater to support fish life), Directive 79/923/EEC (on the quality of shellfish waters) and Directive 91/492/EEC (on the protection of consumers of shellfish).

[3] For example, Directive 91/493/EEC prescribes sanitary rules governing the production, distribution and sale of fishery products and Directive 91/67/EEC prescribes sanitary rules for the distribution and sale of aquaculture products and fish.

[4] Directive 91/493/EEC as amended by 95/71/EC

[5] Directive 91/67/EEC as amended by Directives 93/54/EEC and 95/22/EEC

diseases of salmonids and other aquatic resources, and Resolution No. 530, 1992, regarding appropriate areas for aquaculture in Chile. In most countries there is a need for a revision of the legislation relating to aquaculture due to the expansion of this activity. FAO has been recently involved in a review of fisheries and aquaculture legislation in Ecuador and is currently assisting the Government of Suriname to draft a new aquaculture law.

In the USA, a bill introduced before the Senate in July 1997 provides an interesting example of legislation designed to support the development of private sector aquaculture. The rationale for the National Aquaculture, Development, Research and Promotion Bill, 1997, is the recognition that the development of aquaculture in the USA has been inhibited by a variety of scientific, economic, legal and production factors. These include: inadequate credit, limited research, diffuse institutional responsibility, inappropriate land- and water-use management policies, and the lack of management information, supportive federal policies and therapeutic compounds. If enacted, the Bill will amend the National Aquaculture Act of 1980 to require the Secretary of Agriculture to develop and co-ordinate the implementation of a national policy and plan for private aquaculture; to establish a National Aquaculture Information Center as the cornerstone of an on-line network which would facilitate access to information from research institutions and regional aquaculture centres; to provide federal funding for commercially relevant research which would create employment and promote the sustainable development of aquaculture; to make aquaculture eligible for farm credit assistance; and to authorize the Secretary to establish an international aquaculture information collection programme.

Stock enhancement and ocean ranching have been practised for decades for salmonids in several countries, and for a wide variety of marine fish and invertebrate species in Japan. The lessons and new techniques resulting from these experiences have encouraged consideration of stock enhancement for increasing the productivity of existing fisheries, for creating new fisheries and for restoring those that are no longer viable. With respect to the legal implications there are a number of issues that need to be solved both at the national and international levels, such as property rights over released fish in jurisdictions where natural fish stocks are not normally the subject of private and/or national ownership, and problems relating to the lawfulness of methods of recapture.

The need to develop policies and a legal framework for aquaculture is now widely recognized. The challenge that many countries are only beginning to address is the need to review, and if necessary reform, the whole regulatory framework applicable to aquaculture to ensure that unnecessary legal and bureaucratic obstacles are removed, and that the necessary incentives and penalties exist to ensure that the sector develops in a sustainable manner. Governments need to continue to explore and develop legal and institutional instruments to: (a) recognize aquaculture as a distinct agricultural sector; (b) integrate aquaculture concerns into resource use and development planning; (c) improve food safety and quality to safeguard consumers and meet the standards of importers; and (d) improve the management of aquaculture, particularly where it has the potential to be socially or environmentally unsustainable.

In strengthening legal and institutional frameworks for aquaculture, governments would be well advised to consult with private aquaculturists to identify factors which may be inhibiting development. The principles set out in the CCRF and the Draft Code of Hygienic Practice for the Products of Aquaculture also provide useful guidance in this regard. In addition, the development of criteria and indicators which could be used to begin to measure whether or

not a specific type of aquaculture is likely to be environmentally, economically and socially sustainable, would be of great assistance in refining regulatory frameworks.

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2.7 International Trade

Lem, A. and Z. H. Shehadeh

International seafood exports reached US$52 thousand million in 1995, up from US$35.8 thousand million in 1990. The share of exports from developing countries grew from 44% in 1990 to 51% in 1995 and net receipts of foreign exchange rose from US$10.4 thousand million to US$18 thousand million in the same period. The rapid growth in aquaculture production has made the sector important to the economy of many developing countries and, in the case of some traded aquatic products, the sector has become either an important source of supply or the main supplier. In these cases, fluctuation in production of farmed products has significant impact on price trends. In general, however, aquaculture products have helped to stabilize supplies of traded products and to bring down prices over the years. This has made what were previously luxury products available at lower prices and has helped expand markets.

The extent of regional and international trade in aquaculture products is difficult to analyze because trade in many aquaculture products is not yet well documented in the main producing countries, and because international trade statistics do not distinguish between wild and farmed origin. Thus, the exact nature of these categories in international trade is open to interpretation. This situation will change gradually as producers' associations emerge in the main producing countries and begin to keep records, and in response to various trade regulations/pressures which distinguish between farmed and fished products.

Major aquaculture products traded

The main traded products from aquaculture in 1995 were shrimp and prawns, salmon and molluscs. Other species showing strong growth in trade are tilapia, seabass and seabream.

Crustaceans. The most prominent product from aquaculture in international trade is marine shrimp and aquaculture has been the major force behind increased shrimp trading during the past 7-8 years. Shrimp is already the most traded seafood product internationally, and in 1996 about 25% or 700,000 mt came from aquaculture (Rosenberry, 1996). Since the late 1980s, farmed shrimp have tended to act as a stabilizing factor for the shrimp industry. Therefore, the major crop failures in Asia and Latin America during the past few years have had an impact on overall supply, demand, prices and consumption trends. For example, shrimp consumption declined in the US in 1995 due to lower imports caused by declining supplies from Asian countries.

The major markets are Japan, the USA and, to a lesser extent, the European Union (EU). The largest exporters of farmed shrimp (during the first nine months of 1996) are Thailand, Ecuador, Indonesia, India, Mexico, Bangladesh and Vietnam (Branstetter, 1997). The contribution of farmed shrimp to total domestic production in these exporting countries is shown in Table 2.7.1. Demand for shrimp and prawns is expected to increase in coming years. Asian markets such as China, the Republic of Korea, Thailand and Malaysia, will expand as local economies grow and consumers demand more seafood. This trend is already reducing the availability of shrimp to traditional importers and will eventually put upward pressure on prices if supplies do not expand. Increase in prices will encourage new entries into shrimp farming, if sustainable methods of production are practised that would help avoid production crashes, national curbs on production expansion, or trade embargoes.

Trade in crab species has increased with growing aquacultural production (1995: 98,000 mt). Especially important have been the exports of mainland China (21,000 mt in 1995) to Hong Kong and Japan.

Table 2.7.1. Contribution of aquaculture to national shrimp production, 1995.

Country	% of total production
China	13
Ecuador	90
India	32
Indonesia	43
Mexico	18
Thailand	69
Viet Nam	30

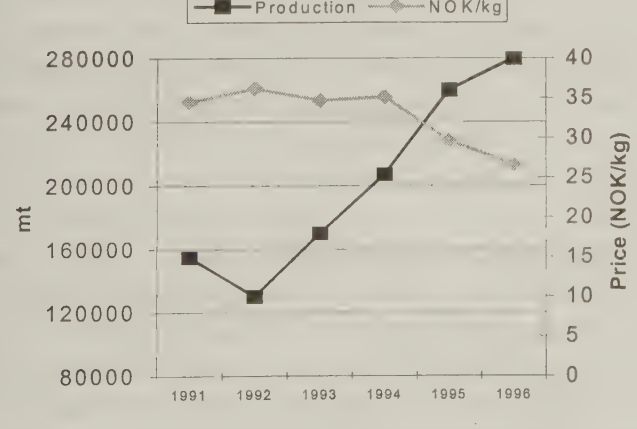
Source: FAO, 1997c

Finfish. In terms of total aquaculture output, finfish production ranks first with 14.7 million mt produced in 1995, or about 53 % of the total production from aquaculture. The major part of this is carps (69% of total finfish production in 1995), which are consumed locally in the producing countries (mainly China and India).

International trade in farmed salmon has increased from virtually zero to more than 500,000 mt (1996) in less than a decade. The traded species are Atlantic salmon and, to a much lesser extent, coho salmon, which accounted for 87% and 11% of production in 1995, respectively (FAO, 1997a). Growth in trade has followed the growth in salmon production, as the bulk of production is concentrated in a few countries with limited domestic markets--Norway, Chile and the UK. Norway is the main exporter of Atlantic salmon; Chile is the main exporter of coho salmon and second largest exporter of Atlantic salmon. The EU is the main market for Norway (70% of exports); Japan and the US are the main markets of Chile (60% and 30% of exports, respectively). Norway has targeted Asia as the future growth market in addition to further penetration of the European markets, and more than US$7.25 million was spent in 1996 on promoting salmon and trout. Chilean producers foresee strong growth in the USA and Latin American markets and more emphasis in the industry on value-added products (FAO, 1996; Lem and Di Marzio, 1996). With increased production volumes, costs and prices have been driven down, and at current levels (US$3.50-4.00/kg CIF), salmon has become a relatively medium-priced product in international seafood markets (Figure 2.7.1).

International trade in trout is much less that in salmon, with exports reaching 55,000 mt in 1995 out of a total production that year of 384,000 mt. Consumption is concentrated in trout-producing countries, but Norway and Chile have begun to farm quantities of large, heavily pigmented trout for the Japanese market: Japanese 1996 trout imports were 36,500 mt.

Figure 2.7.1. Norwegian salmon production and export prices



Tilapia is another species group that has shown a tremendous growth in output (660,000 mt in 1995). International trade is limited but growing, especially between Central America (Costa Rica, Ecuador and Colombia) and the USA, and between Asian producers (Taiwan Province of China, Indonesia and Thailand) and the USA and Japan. There is also modest trade between Jamaica and the UK. The biggest exporter, Taiwan Province of China, supplies Japan with high quality tilapia fillets for the sashimi market and ships frozen

tilapia to the American market, with total exports of 16,000 mt in 1996. Taiwan Province of China exports about 5% of its tilapia production and supplies 79% of the US tilapia imports (1996 data) (Table 2.7.2). Thailand and Indonesia export less than 5% of their production (Dey and Eknath, 1997). Viet Nam has also recently entered the world tilapia market and China exported the fresh weight equivalent of 122 mt to the USA in 1996.

Table 2.7.2. U.S. tilapia imports by country in 1996 (quantities = fresh weight equivalent)

Country	Quantity (mt x 1,000)	Value (US $ x 1,000)
Taiwan China	15.032	24,822
Costa Rica	1.082	5,887
Ecuador	0.960	3,661
Indonesia	0.579	2,684
Thailand	0.284	1,489
Jamaica	0.246	1,399
Colombia	0.225	1,276
Honduras	0.210	914
Belize	0.153	226
China	0.122	267
Other	0.151	393
Total	**19.044**	**43,018**

Source: USDA, 1997

Tilapia is now the third largest imported aquaculture product in the USA (1996 imports of 19,000 mt), after shrimp and salmon. Imports were up 21% by quantity in 1996, following an increase of 33% in 1995, and are forecast to increase further in 1997. Long-term tilapia prices are expected to decrease and this should lead to greater exports to the USA as well as to Europe, presently undeveloped as a market for tilapia.

In Europe, the seabream/seabass industry intends to copy the success of salmon growers. Production reached about 60,000 mt in 1996, of which nearly 90% was exported, mainly to Italy and Spain (FAO, 1997a). The main exporter was Greece, with about 70% of production exported. Italy has been almost the exclusive market for Greek production. However, as a result of market development efforts, about 15% of Greek exports in 1995 went to new markets (UK, Germany, France, etc.) and the share of such markets is expected to grow (Stephanis, 1996). Trade in fingerlings was from Italy, Spain and France to farms in Greece, Malta and Croatia.

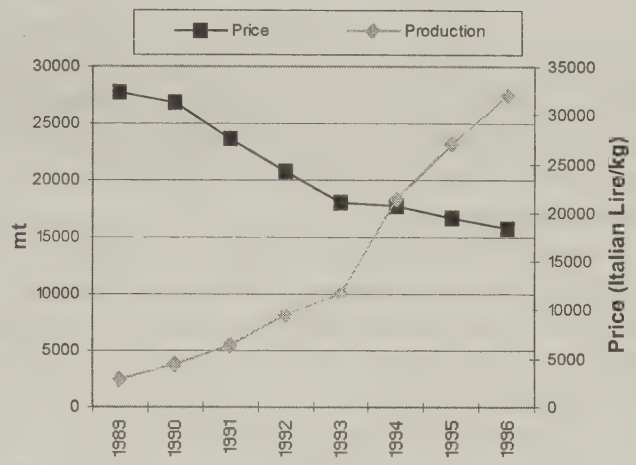
As output of seabass/seabream has grown, costs have been driven down, and market prices have almost been halved during 1990-1995, from US$16/kg to around US$8/kg (Figure 2.7.2). The rapid saturation of the market and the parallel rapid decline in prices (50% in five years, compared to 50% in ten years in the case of Atlantic salmon) is attributed to the much smaller traditional market for these species (in southern Europe) compared to that for Atlantic salmon, lack of diversified products, inadequate market development, and absence of technological advances (e.g. genetic improvement, efficient feeds and feeding strategies) which could significantly improve productivity. The substantial drop in price of these species should help open new markets and expand existing ones, provided acceptable profit margins can be sustained at the production end through improvements in productivity and diversification of products.

American catfish is now the fifth most consumed fish in the USA (0.36 kg per capita edible weight in 1995). Exports are limited as the production is aimed at the domestic market, but producers have recently started exporting to Europe. The reason for the success of catfish is similar to that of tilapia: consumer demand for white, easy-to-prepare, fillets.

Seaweed Farmed seaweed production has been growing in the last decade (6.1 million mt in 1995) and is now 86% of total seaweed supplies. Most output is used domestically for food,

but there is growing international trade. China, the major producer, has started exporting seaweed as food to the Republic of Korea and Japan. The Republic of Korea in turn exports some quantities of *Porphyra* (red seaweed) and *Undaria* (brown seaweed) to Japan (total 1996 exports from the Republic of Korea: 21,000 mt).
Significant quantities of *Eucheuma* (red seaweed), are exported by the Philippines, Tanzania and Indonesia (total Indonesian 1995 exports: 18,000 mt) to the USA, Denmark and Japan. Total EU imports of seaweed in 1995 amounted to 58,000 mt with the Philippines, Chile and Indonesia as the biggest suppliers.

Figure 2.7.2. Sea bream production and price development



Source: Wholesale prices, fish market, Milan, Italy.

Molluscs. International trade in molluscs is relatively limited, with less than 10% of total output traded. Major importing markets are Japan, USA and France, and major exporters are China and the Republic of Korea. The contribution of farmed products to trade is uncertain.

Farmed mollusc production volumes are fairly evenly split between oysters, clams, mussels and scallops, but in international mollusc trade 70% of value is concentrated in scallops and clams (fresh and frozen). Total fresh and frozen scallop imports have grown from 28,000 mt in 1985 to 60,000 mt in 1995, reaching US$493 million. Clam imports have grown from 33,000 mt to 178,000 mt in the same period, valued at US$295 million. Mussel imports were showing a downward trend after a peak of 175,000 mt in 1992 but have now levelled out at 130,000 mt with a value of US$188 million. Oyster imports have been growing steadily from less than 10,000 mt in 1985 to 30,000 mt in 1994 and seem now to have stabilized at this level (1995: 27,000 mt, US$140 million.).

Live Seafood. Asia is rapidly increasing its consumption of live seafood as a result of cultural preferences and growing affluence. The live seafood market is largely restricted to the restaurant trade and to consumers with a relatively high disposable income. Major market expansion is anticipated due to demand in China, but expansion is also expected in Malaysia, Singapore, and Taiwan Province of China, as well as in parts of North America with large Chinese communities. The potential for aquaculture to supply the market is promising. The sector is already supplying large amounts of shellfish and limited quantities of grouper, crabs and other species. Technological developments in the culture of preferred live-food species will increase the contribution of aquaculture to supplies (Riepen, 1997).

Seed supplies. There appears to be significant regional and international trade in seed of cultured aquatic organisms, mainly from aquaculture sources, but this is poorly documented at present in most instances. Mention has been made above of regional trade in Mediterranean seabass and seabream; there is also trade in glass eels (e.g. recent large purchases of European eel elvers by China), post-larvae of various cultured shrimps, Indian and Chinese carps, and others. There is also limited trade (in terms of quantity) in broodstock. Documentation of

trade in seed will improve gradually in response to concerns about spread of diseases and the movement of genetic material.

Issues affecting future trade in aquaculture products

Externalities. Environmental and social concerns have already influenced farmed shrimp exports to North America and Europe in 1997. The importance of attaining sustainable aquaculture with no or limited externalities will force many exporting countries to adopt more sustainable production practices. The introduction of eco-labeling schemes will further increase this trend.

Quality. With growing concern about food safety, increasing efforts have been undertaken to improve the quality of aquaculture products. International codex standards cover aquaculture products, and the introduction of mandatory HACCP requirements for exports to the USA and the European Union in 1997 will have strong impact on trade in aquaculture products in the near future. Some countries have developed comprehensive HACCP plans for selected aquaculture products; for example, the USA now has plans for catfish, crawfish and molluscan shellfish. In other countries, individual aquaculture producers undertake voluntary certification (ISO 9000) for control as well as marketing purposes.

Tariffs. Despite steady reductions in tariffs on fish and aquaculture products in recent years, tariffs as well as import licenses continue to represent barriers to trade in many countries. This is especially the case in many fast-growing economies in Asia, but important markets such as Japan, the European Union and the USA all give competitive advantages to domestic producers of many species, especially in the case of processed products. Average tariffs on imports from developing countries are now estimated at 4.8%, a cut of 27% from the previous level of 6.6% (FAO, 1995). The long-term trend, with growing membership in the World Trade Organization, will be for further reductions in tariffs.

Food security. Aquaculture is an important source of seafood because most of the production is consumed domestically by producing nations. It has also become a significant source of foreign currency to many developing nations because the products exported usually are the more valuable ones, destined for markets in the developed world. These revenues allow the countries to import other less costly protein, and as such, aquaculture can be considered important to food security even when the output is exported.

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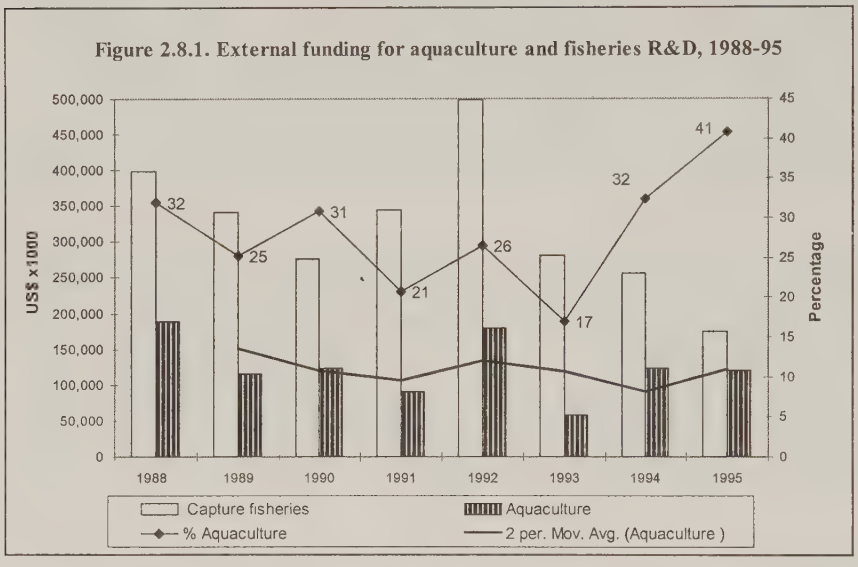
2.8 External Assistance

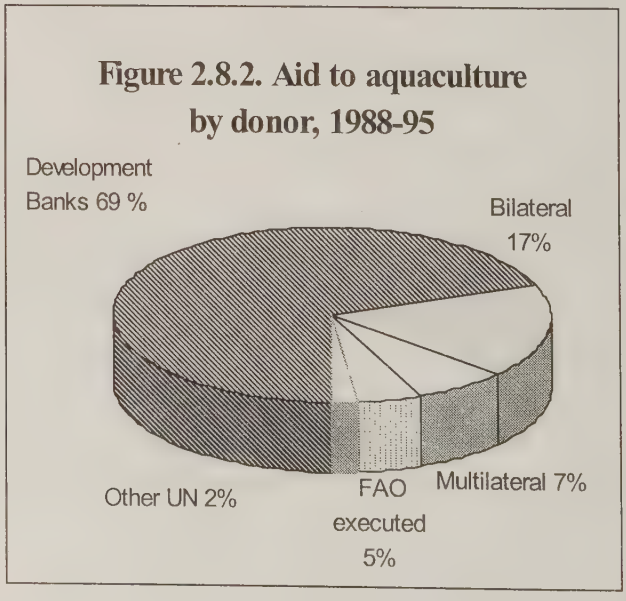
Shehadeh, Z.H. and J. Orzeszko

Information on grants and loans for aquaculture research and development is maintained within the Fisheries Project Information System (FIPIS) by FAO from data supplied by donor agencies. In FIPIS, funds committed to projects are allocated entirely to the year in which the projects became operational. Therefore, data presented here for each year refer to the number of projects beginning that year and the total funds committed to the projects. Following is an analysis of current information in the system. Some data returns from donors are incomplete for 1995, so the analysis should be considered provisional.

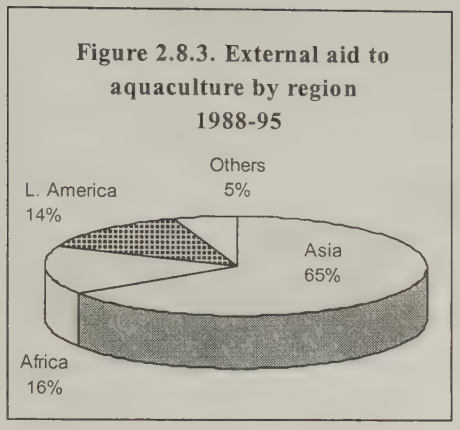


Total official aid to aquaculture research and development in 1988-95 was about US$995 million, expressed in current value terms, and represented about 28% (range: 25-40%) of the total committed to the aquaculture and fisheries sectors (US$3.6 thousand million). The average annual input was about US$124 million per year. With the exception of two years (1991 and 1993), annual inputs (funding for new aquaculture projects) during the period were fairly steady with a range of US$120-188 million; the maximum proportion of aquaculture assistance was in 1995, as a result of the continuing drop in funding for capture fisheries since 1992 (Figure 2.8.1).

About 578 aquaculture projects were initiated during the period, accounting for 26% of the total number of projects in fisheries and aquaculture. An additional 54 projects with aquaculture components were also initiated during the period. The total number of fisheries and aquaculture projects commenced each year declined gradually over the eight-year period from 379 in 1988 to 132 in 1995, and from 114 to 21 in the case of aquaculture projects.

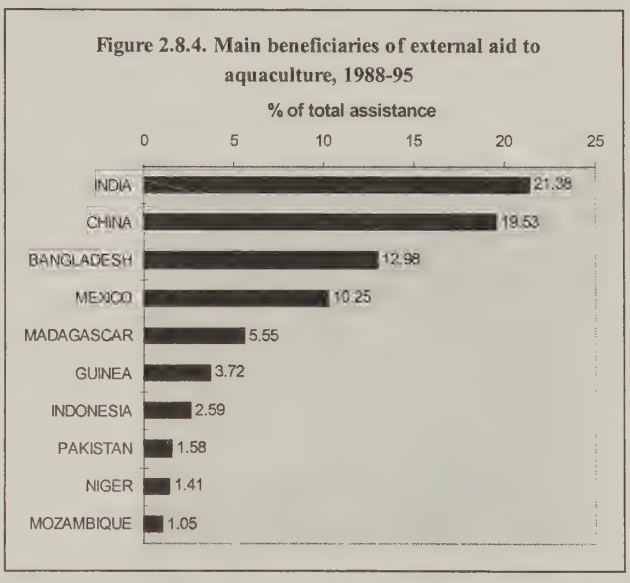


Development banks were consistently the main source of external funding for aquaculture during 1988-1995 (Figure 2.8.2). They accounted for 69% of the funding and 40% of the projects, while bilateral sources contributed 17% of funding



and accounted for 6% of the projects. Multilateral sources contributed 34% of projects and 7% of funding. Projects executed by FAO, which were supported by the FAO Technical Co-operation Programme, Trust Funds and the United Nations Development Programme, amounted to 5% of funding and supported 18% of projects initiated in the period. A further 2% of projects came from other UN agencies (2% of funding). In 1994, the last year for which complete data are available, the banks and bilateral agencies accounted for 91% of funding (74% and 17%, respectively). Data so far available for 1995 show increasing dominance of funding by the development banks (92%) with the meagre balance contributed by bilateral (3%) and multilateral (5%) sources.

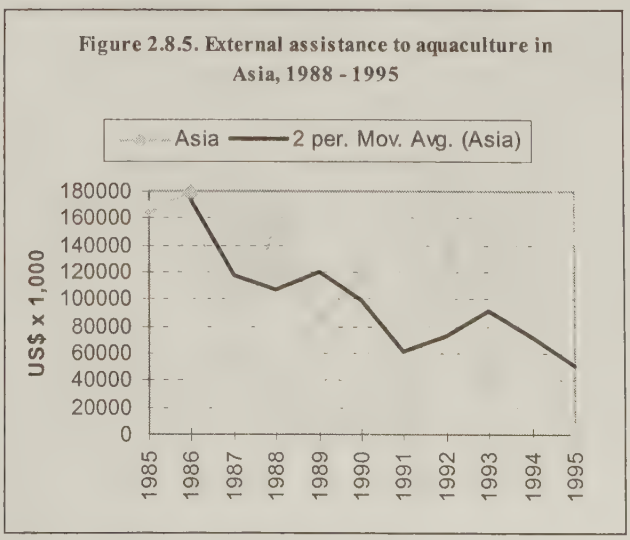
The Asian and African regions consistently received the greatest measure of support with regard to the number of projects commenced and the funds allocated (Figure 2.8.3). Of the total number of projects reported to FIPIS for the period 1988-1995, the Asian region accounted for 65% of commitments and 38% of the projects, while African countries were the recipients of 16% of commitments and about a quarter of the projects. Of the remaining regions, only Latin America commanded a substantial part of aid, with about 14% of funds and 17% of projects.



Interestingly, average annual aid to Oceania (US$1.5 million) was higher than that to the Near East and Mediterranean (US$1.3 million), the Caribbean and Atlantic (US$0.6 million), and Europe (US$0.2 million). Assistance through global and inter-regional projects accounted for 2.3% of aggregate funding for the period, and 10% of projects.

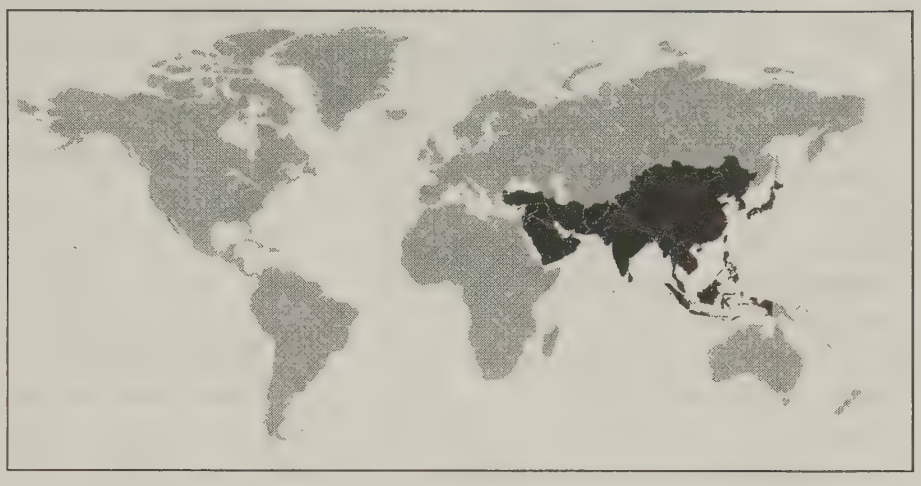
The major beneficiaries of aquaculture aid during 1988-1995 (i.e. countries receiving at least 1% of total aid) are shown in Figure 2.8.4. India, China, Bangladesh and Mexico, which have received major loans from development banks during the period, accounted for about 64% (about US$638 million) of external aid to aquaculture.

The two notable trends in external assistance to aquaculture, as seen from FIPIS data, are the continuing dominance of development banks and the decrease in commitments of aid to aquaculture in Asia (Figure 2.8.5).



3. REGIONAL REVIEWS

3.1 Asia



China, East Asia, Southeast Asia, South Asia, West Asia

Tacon, A.G.J.

Asia's contribution toward total world aquaculture production increased from 83.8% to 90.1% from 1984 to 1995, with production in 1995 at 25.0 million mt (up by 10.1% from 1994) valued at US$34.8 thousand million (up by 5.5% from 1994) or 82.3% of total world aquaculture production by value (Figures 3.1 and 3.2). The average growth of the aquaculture sector in Asia has been more than twice that in the rest of the world, with the sector displaying an APR[1] of 10.4 by weight since 1984 (12.7% by value) compared with 4.3% by weight or 9.8% by value for all other countries (Figure 3.1). Aquaculture production has been growing more than four times faster than landings from capture fisheries (APR of 2.2 since 1984), with aquaculture's share of total fisheries landings in the region increasing nearly two fold from 20.7% in 1984 to 38.0% in 1995 (Figure 3.3). The top seven aquaculture-producing countries in the world were all Asian: China, India, Japan, Republic of Korea, Philippines, Indonesia and Thailand; these seven countries produced 85% of world aquaculture production in 1995.

Figure 3.1. Contribution of Asia toward total world aquaculture production by weight (mt).

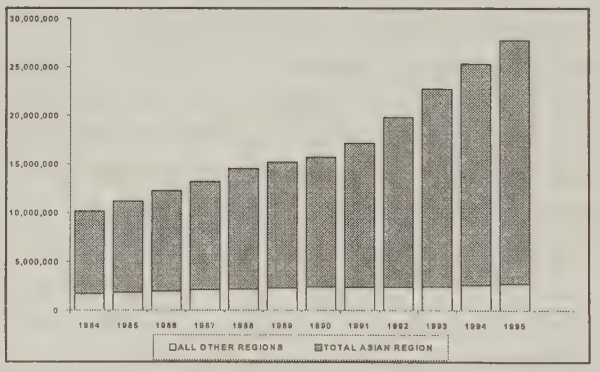
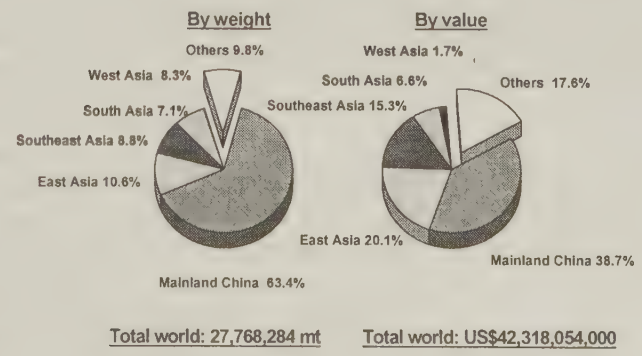


Figure 3.2. Contribution of major Asian regions to total world aquaculture production in 1995



In terms of food supply (i.e. finfish and shellfish, live weight equivalent) the region produced over 87% of total world food fish production from aquaculture in 1995, compared with only 36% in the case of

[1] Annual Percent Rate: average annual compounded growth rate in percent.

terrestrial animal meat products. According to the latest FAO fishery food balance sheets (Laureti, 1996), although per caput food fish supply within the region was only 13.9 kg in 1993 (fourth in rank after Oceania, Europe and North America), total food fish supply (including landings from both capture fisheries and aquaculture) has been increasing at an average rate of 3.3% per year since 1984, and it is estimated that the share of aquaculture is currently about one third of this.

Table 3.1 summarizes the contribution of the Asian region to total world aquaculture production by major species groups. The proportion of freshwater species production in the region increased from 37.2% to 49.1% from 1984 to 1995, an average annual rate of 13.2%. By contrast, the proportion of aquaculture production in brackishwater environments decreased from 5.4% to 5.0%, and that of marine production decreased from 57.4% to 46.0% in the same period, with annual production increases averaging 9.6% and 8.2% by weight, respectively.

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Figure 3.3. Contribution of aquaculture toward total fisheries production in Asia

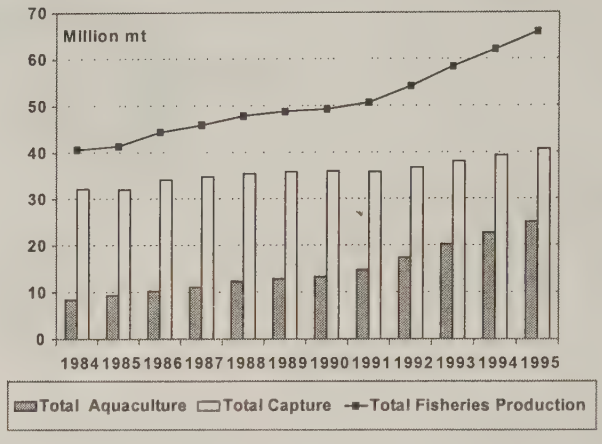


Table 3.1. Asia's contribution to total world aquaculture production (%) by major ISSCAAP grouping.[2]

ISSCAAP group	1984	1995
Finfish	**81.5**	**89.1**
• Carps, barbels, cyprinids-11	85.4	98.3
• Tilapias, cichlids-12	78.1	85.5
• Misc. freshwater fish-13	68.2	82.2
• Salmon, trouts, smelts-23	15.6	6.8
• Misc. diadromous fish-25	99.9	99.9
• Redfishes, basses-23	97.6	98.9
• Jacks, mullets-34	97.8	91.1
Crustaceans	**71.5**	**83.9**
• Shrimp-45	78.0	84.0
• Freshwater crustaceans-41	25.3	45.8
Molluscs	**59.1**	**82.4**
• Oysters-53	63.7	72.5
• Mussels-54	29.9	54.4
• Scallops, pectin-55	98.9	99.2
• Clams, cockles-56	97.4	91.8
Aquatic plants	**99.7**	**99.0**
• Brown seaweeds-91	99.9	99.8
• Red seaweeds-92	99.2	96.2
• Green seaweeds-93	100.0	100.0
Misc. animals/products	**98.9**	**98.2**

[2/] ISSCAAP – International Standard Statistical Classification of Aquatic Animals and Plants.

3.1.1 China[1]

Rana, K.J.

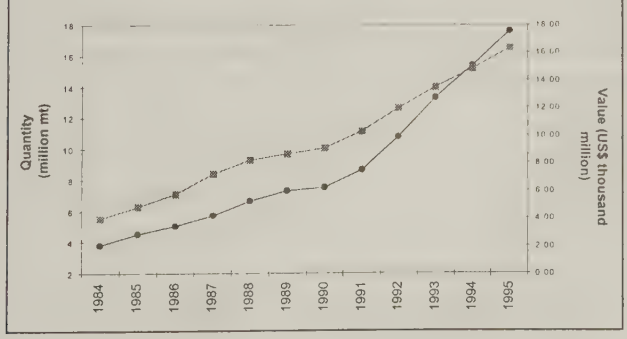
The low per caput share of land resources in China is likely to be inadequate to meet the increasing demand for animal protein. Per caput agricultural land decreased from 0.19 ha in 1949 to 0.09 ha in 1995 (Wu, 1996). This, together with recent concerns on declining wild fish stocks, has focused Chinese fishery development policies on expanding inland, brackishwater and marine aquaculture (Qian, 1994).

The significance of Chinese aquaculture only became evident in the 1950s. Prior to this time, the Yangtze and Pearl River deltas were the principal areas for fish culture, producing some 15,000 mt annually in the 1940s. Since the 1950s, and particularly since the 1980s, the culture of fish in fresh-, brackish- and marine waters has expanded rapidly in all but two provinces, Qingha and Xizang (Tibet), where the harsh climate and topography of the Tibet-Qingha plateau limits production (Qian, 1994). By 1995, annual production reached 17.6 million mt of aquatic finfish, shellfish and plants, valued at US$16.3 thousand million (billion), from a total of around 6.4 million ha in inland and marine areas.

Production and production trends

China continues to dominate global aquaculture with 63.4% of world aquaculture production in 1995. China accounted for 70.4% of Asian production in 1995, but only 47.3% of its value, due to the relatively low value of cultured species, mainly carps. The output of Chinese fisheries (capture and culture) increased at an APR of 13.0 between 1984 and 1995. This increase, however, was not linear; between 1990 and 1995, Chinese fisheries production increased at an APR of 16.0. The greater part of this increase was due to aquaculture: an APR of 18.5 compared with 12.7 for capture fisheries. The contribution of aquaculture to Chinese fisheries increased from 51.6% in 1990 to 60.5% in 1995, during which period aquaculture production rose from 7.5 million mt to 17.6 million mt, or from a value of US$4 thousand million to US$16.3 thousand million (Figure 3.1.1.1).

Figure 3.1.1.1. Chinese aquaculture production trends in China



Between 1984 and 1995, the total tonnage from fresh-, brackish- and marine waters reported as aquaculture increased at an APR of 13.6, 13.5 and 16.1, respectively, and in 1995 totalled 9.4 million mt, 0.1 million mt and 8.1 million mt, respectively. During this period, the value of cultured aquatic products from freshwater, brackishwater and

[1] China, SAR of Hong Kong and Taiwan Province of China are reviewed under East Asia.

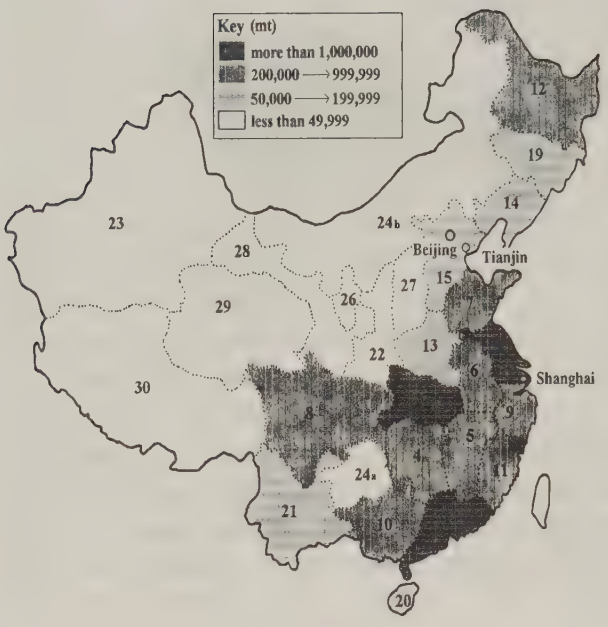


Figure 3.1.1.2. The administrative divisions of the People's Republic of China, showing ranked freshwater aquaculture production for 1995 in each area. (Map courtesy of Anton Immink)

The provinces and autonomous regions are:
(1) Guangdong, (2) Hubei, (3) Jiangsu,(4) Hunan, (5) Jiangxi, (6) Anhui,(7) Shangdong,(8) Sichuan, (9) Zhejiang,(10) Guangxi, (11) Fujian,(12) Heilongjiang, (13) Henan, (14) Liaoning, (15) Hebei, (19) Jilin, (20) Haina, (21) Yunnan, (22) Shaanxi, (23) Xinjiang, (24a) Guizhou, (24b) Nei mongol, (26) Ningxia, (27) Shanxi, (28) Gansu, (29)Qinghai, (30)Xizang (Tibet). The Municipalities are: Shanghai (ranked 16), Tenjing (17) and Beijing(18). (Data adapted from Lem, 1997)

marine environments increased at an APR of 13.9, 13.4 and 17, respectively, and in 1995 reached values of US$8.4 thousand million, US$0.6 thousand million and US$7.3 thousand million, respectively.

Many factors have influenced the rate of aquaculture development in the different provinces: the large variation in Chinese climatic conditions; water availability; patterns of urbanization and industrial development; increasing economic status of the Chinese population; high urban per caput fish consumption of around 8-10kg (Lem, 1997); China's open-door policy in the 1980s; and the nation's determination to increase non-staple food production and supply. The warmer climate, tradition of aquaculture, and proximity to urban and international markets have placed the southern provinces of Guangdong, Hubei, Jiangsu, Hunan, Jiangxi, Anhui, Shangdong, Zhejiang, and Guangxi amongst the top 10 freshwater fish-producing provinces in China, accounting for around 78% of Chinese freshwater production (Figures 3.1.1.2 and 3.1.1.3).

The ranking of Chinese provinces in freshwater production recorded as aquaculture in 1995 is shown in Figure 3.1.1.2. The highest ranked provinces, Guangdong, Hubei and Jiangsu, produced 1.48, 1.31 and 1.29 million mt of freshwater fish, respectively, in 1995. The national average growth rate of freshwater aquaculture in all Chinese provinces during 1992-1995 was 20%, with the average APR of individual provinces ranging from 4 to 43. Provinces with a lower production base have tended to expand at a faster rate (Figure 3.1.1.3).

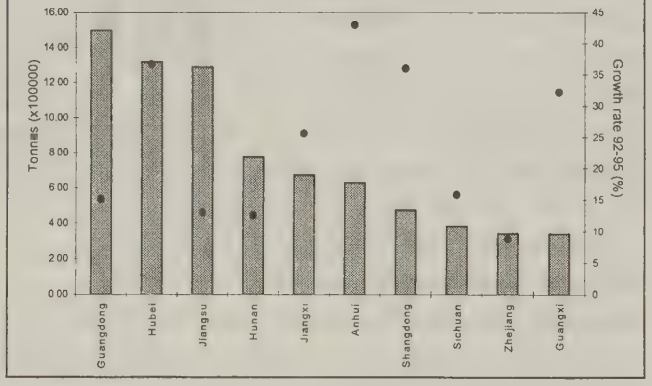
In keeping with Chinese policy of developing inland aquaculture as a strategy for rural industrial development, and to meet the demands for inland and northern conurbations, freshwater aquaculture has expanded rapidly northwards since the 1980s into northeastern, western and northern regions to provinces such as Hebei, Henan, Shanxi, Shaanxi, Liaoning, Jilin, Heilongjiang, Inner Mongolia, Gansu, Ningxia, Qinghai and Xinjiang. In 1995, these provinces accounted for around 0.9 million mt or 9.5% of national freshwater fish production. Even though production from the inland provinces was relatively low (1,000-35,0000 mt), the sector expanded by 12-26% per year between 1992 and 1995. Production of freshwater fish in the northern provinces was higher: Heilongjiang, Liaoning and Jilin, where annual production from 1992 to 1995 increased by 16%, 22% and 10%, respectively, reported 2.01, 1.58 and 0.78 million mt of freshwater fish, respectively, in 1995 (Lem, 1997).

Use and development of natural resources for aquaculture production

The development of aquaculture in China has focused on increasing production from both inland and marine waters. Since 1984, the area and intensity of production of ponds, and the use of open waters such as lakes, reservoirs, rivers and paddies for freshwater aquaculture, have steadily increased at an APR of 2.8 (adapted from Qian, 1994; Anon., 1996; Zhao, 1997). Pond area expanded at an average of 4.0% annually in the same period, and even faster between 1991 and 1995: 6.9% per year (Figure 3.1.1.4).

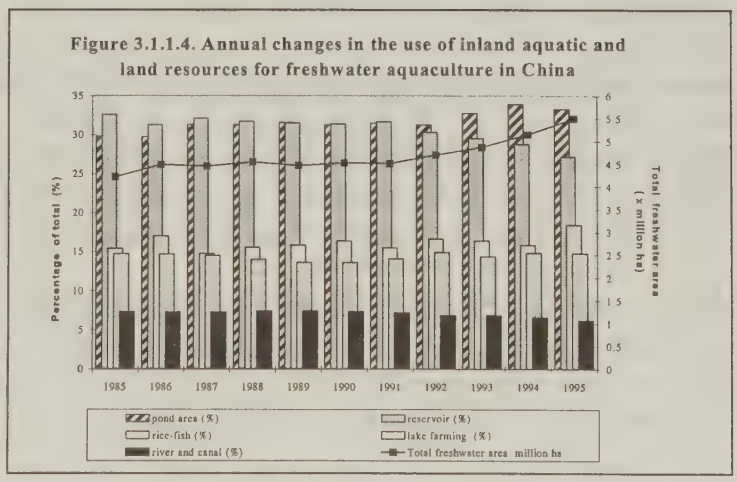
Ponds and reservoirs are the principal types of water bodies used for freshwater aquaculture production and in 1995, 1.86 and 1.51 million ha, respectively, were exploited for aquaculture (Zhao, 1997). In the last five years, increased production has also been achieved through increased yields. For ponds, national average yield has increased from 1,390 kg/ha in 1985 to around 4,000 kg/ha in 1995. In Guangdong, pond yields of over 6,600 kg/ha were attained in 1995. Ponds accounted for 73% or 6.9 million mt of freshwater production in 1995 (Zhao, 1997).

Figure 3.1.1.3 Production of freshwater fishes in 1995 in the top 15 Chinese provinces and their corresponding sector growth rate (o) between 1992-1995.



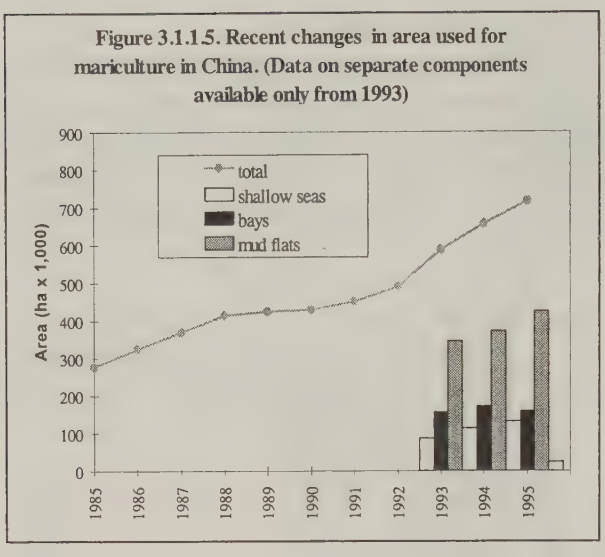
To meet the growing national demand for high-value marine products, an increasing proportion of the available 2.6 million ha of inter-tidal mudflats, shallow seabeds and bays is being developed for aquaculture. Between 1985 and 1995, the total area used for mariculture rose on average by 10% per year from 277,000 ha to 715,000 ha (Figure 3.1.1.5, modified from Qian, 1994; Anon.,1996; Anon., 1997; Zhao, 1997). Between 1992 and 1995, annual expansion of mariculture increased to 13.4%. All coastal provinces have expanded their mariculture activities, especially Liaoning and Shangdong in the north and Jiangsu, Fujian and Guangdong provinces in the south. Nationally, emphasis has been placed on expanding culture in shallow seas and inter-tidal mudflats. The area of shallow seas, bays and inter-tidal mud flats under culture increased from 87,000 ha, 155,000 ha and 345,000 ha, respectively, in 1993 to 131,000 ha, 159,000 ha and 425,000 ha in 1995 (Figure 3.1.1.5). During this period, the area of shallow seas and mudflats used mainly for shellfish production, expanded annually at 23% and 11% , respectively.

Figure 3.1.1.4. Annual changes in the use of inland aquatic and land resources for freshwater aquaculture in China



Main cultured species groups and species

Recent production of major groups of aquatic organisms is shown in Figure 3.1.1.6a. Freshwater finfish production has shown rapid growth since 1991 and is the largest



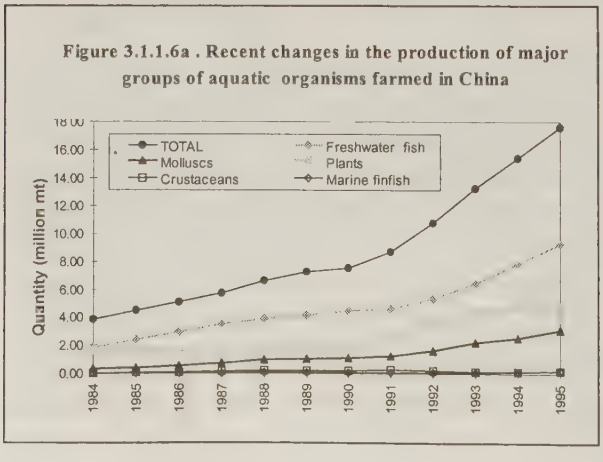
aquaculture activity; in 1995, it accounted for 53% of total aquaculture production. Aquatic plant production stabilized after 1993, and in 1995 represented 27% of total aquaculture production. Marine finfish and mollusc production has increased sharply since 1990, accounting for 1% (Figure 3.1.1.6b) and 17%, respectively, of total aquaculture production in 1995. Production of crustaceans, mainly fleshy prawns (*Penaeus chinensis*) and freshwater crabs, increased up to 1991 and then fell due to disease-related problems and sub-optimal management. The decline in shrimp production was offset by a subsequent increase in freshwater crab production. By 1995, crustaceans accounted for 1% of total aquatic production.

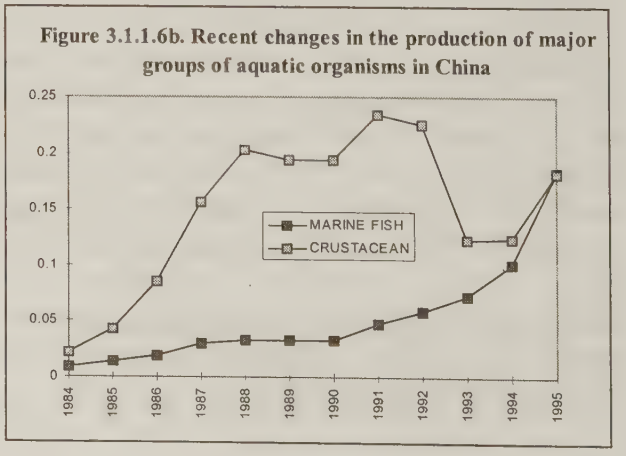
In recent years, China has reported production data of ten freshwater, one brackishwater and seven marine species to FAO. In addition, an increasing quantity of unidentified cultured freshwater fishes has also been reported: 645,000 mt in 1995. Similarly, for marine organisms, unidentified finfish and shellfish, and plants in 1995 reached 1.1 million mt and 634,000 mt, respectively.

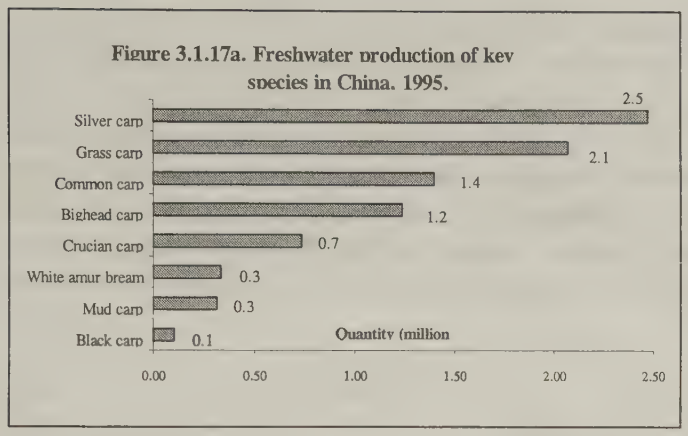
Carp and tilapia species, which are farmed across China, continue to dominate production. Emphasis has been given in recent years to diversify into luxury freshwater species such as mandarin fish, freshwater crabs and prawns, soft shelled turtles and eels. In 1995, the carps accounted for around 99.7% of freshwater fish production and represented 52% and 45% of national aquaculture production by tonnage and value, respectively. Production of silver, grass, common and bighead carps totalled 2.47, 2.07, 1.40 and 1.24 million mt, respectively.

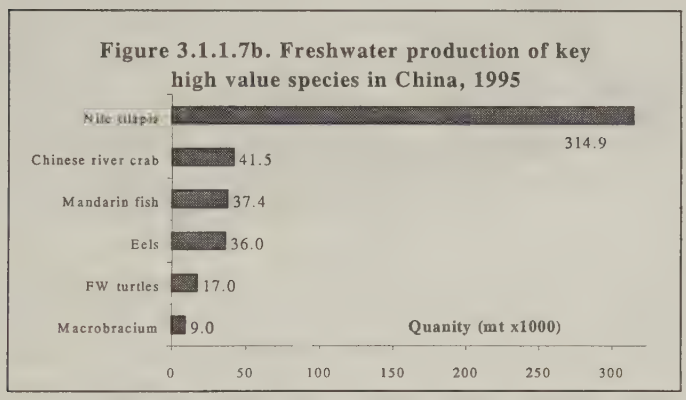
(Figure 3.1.1.7a). Noteworthy was the production of 36,000 mt of eels in 1995, up 25% from 1994; 17,000 mt of soft shelled turtles, up 300%; 41,500 mt of freshwater crabs, up 32%; and 315,000 mt of Nile tilapia, up 35% on 1994 (Figure 3.1.1.7b).

The production of Chinese marine finfish and shellfish, and plants has also increased, on average by 13.6% per year during 1984-1995. Finfish and shellfish production expanded at a fairly uniform annual rate of 22.5%. Annual growth in aquatic plant production accelerated from less than 1% during 1984 to 1990, to 21.8% from 1990 to 1995. The increase in plant





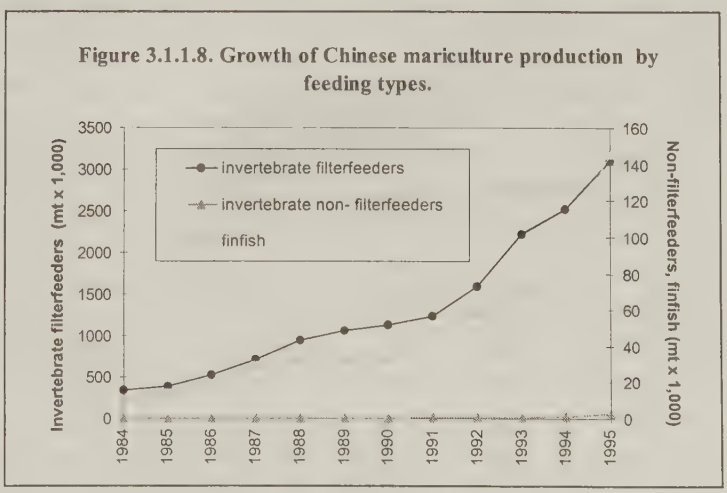




production has not been consistent, however. Between 1990 and 1991, production of kelp, laver and unidentified plants increased by 46%, 120% and 46%, respectively. Between 1994 and 1995, the increase was only 2%, 6% and -6%, respectively.

The expansion of production from the marine environment has been mainly from invertebrate filter feeders such as the Yesso scallop, Japanese carpet shell, Pacific cupped oyster, razor clams and blood cockle (Figure 3.1.1.8), and from plants. The production of cultured filter-feeding invertebrates increased at an APR of 22 from 1984 to 1995, and in 1995, 3.1 million mt were reported. For non-filter-feeding invertebrates, such as marine crabs and other crustaceans, the APR rose dramatically from 8 during 1984-1990 to 70 from 1990 to 1995. In 1995, production of 62,000 mt of crabs and other crustaceans was reported. Total production of filter-feeding invertebrates and plants reached 3.1 million mt and 4.8 million mt, respectively, in 1995 and represented 38.2% and 59.3%, respectively, of total marine production.

In the last five years, the rates at which the production of popular freshwater species, such as most carps (Figure 3.1.1.9) has been expanding is levelling off. Carp production increased sharply from 1991 to 1992--silver and bighead carp by 13%, and grass carp, common carp, crucian carp and white amur by 16-19%. Following a peak increase in 1993-1994, the production expansion of some carps, notably grass carp, silver carp and white amur, decreased. An exception was production of crucian carps, which continued to accelerate and in 1994-1995 increased by 39% (Figure 3.1.1.9). As noted above, plant production increases also slowed markedly in 1994-1995 (Figure 3.1.1.10).

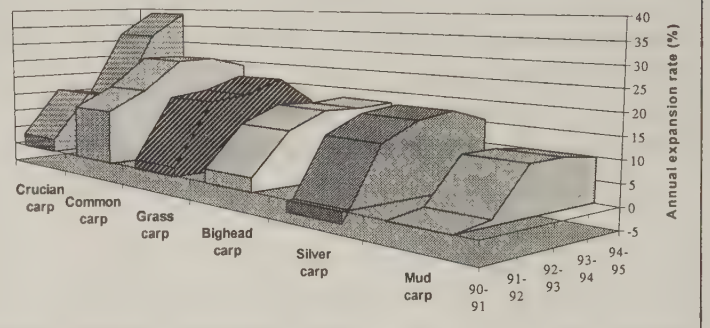


Main issues

Although China's aquaculture production increased five fold between 1984 and 1995, the insatiable demand of its increasing population for high- and low-value aquatic products may not be met in the medium to long term. At present China is a net importer of fish. To address the shortfall in supply, China has made notable strides at the national, provincial and farm

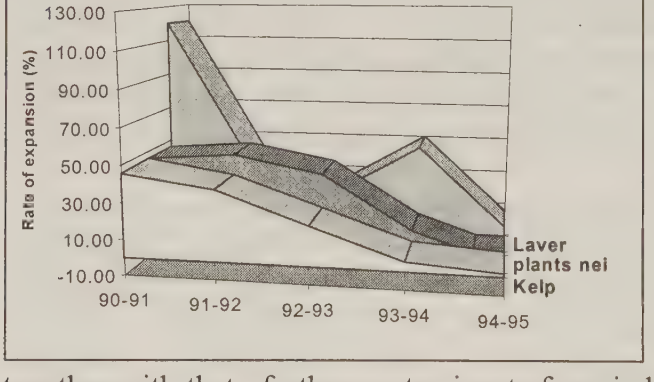
levels in transforming traditional fish farms into modern aquaculture operations with more intensive production, and expanding the area under culture. In the last decade, however, the rapid transformation to a market economy has highlighted several shortcomings in the sector: a) incomplete control of licencing for small-scale farms on private lands; b) competition with other industrial sectors for land and aquatic resources, particularly in coastal regions; c) inadequate infrastructure for the rapidly expanding sector; d) degradation of water quality and culture environments through urbanization, industrialization and uncontrolled intensification; e) limited processing capacity for aquaculture products; f) slow or, in some cases, no implementation of market-oriented policies on price deregulation; g) inadequate fish distribution system; h) managers and workers inadequately trained for modern operations; i) unpredictable fluctuations in the quantity and quality of seed, particularly of high-value freshwater and marine finfish and shellfish species; and j) poorly maintained culture facilities (Qian, 1994; Heping, 1995; Anon., 1996; Anon.,1997).

Figure 3.1.1.9. Changes in annual growth rate of culture of principal carp species in China



All these constraints are being addressed on an ongoing basis, but a few major constraints are likely to determine the stability of aquaculture development. One is the limited availability of choice sites near national and international markets. The expansion of aquaculture may strongly depend on government policies and their implementation related to controlling the quality of the aquatic environment. At present, water quality of several lakes and reservoirs, sections of rivers near cities, and some coastal areas has deteriorated as a result of uncontrolled industrial effluent and domestic discharge. Although hypernutrification and eutrophication, the most serious problems of lakes and rivers, can be beneficial to production, the resultant high oxygen deficits and microbial loading have resulted in high fish losses. The impact on coastal aquaculture of such deterioration, together with that of other contaminants from industrial discharges such as toxic chemicals, heavy metals and organic pollutants, will probably have a significant bearing on the expansion of finfish, shellfish and plant culture. The increasing frequency of red tides, which devastated shrimp farms in Bohai Bay causing an estimated Yuan 400 million loss in 1989 alone, poses a serious threat to development. Similar red tides in 1987 also damaged kelp farms (Heping, 1995). In 1995, economic losses arising from contamination of fish-breeding areas, rivers and shallow seas were estimated at Yuan 560 million (Wu, 1996). These losses, and those likely from banning consumer sales of contaminated products, may increase risk in production and reduce the much-needed confidence and capital influx required to modernize the industry. Under such circumstances, future development will need to be linked closely to monitoring of the environment and provide for compensation for losses caused by activities

Figure 3.1.1.10. Recent decline in the expansion rate of aquatic plant culture in China



outside the sector. At the farm level, attempts to increase yields from ponds may be hampered by a shortage of feeds and lack of pond maintenance.

Outlook

The prognosis for growth is good, despite the constraints given above. The decentralization of aquaculture management and the open-door policy have provided an appropriate framework for increased production. The huge internal market, which is unlikely to be satisfied, and the potential for exporting high-value aquatic products, provide considerable scope for expanding aquaculture.

To overcome the constraints of land shortage, an increasing proportion of the 3 million ha of low-lying and saline-alkaline lands that are unsuitable for agriculture is being developed for aquaculture with assistance from external funding from agencies such as the World Food Programme and World Bank. The success of this strategy, however, is likely to depend on controlling the increasing volume of industrial pollutants originating from rural urbanization. Ponds continue to be renovated and deepened to increase yields. Ongoing attempts to optimize traditional integrated aquaculture and adopt eco-friendly practices have also helped to sustain and increase production.

To meet the new demands of expansion and intensification, more than 1,000 small-scale hatcheries and nurseries, 50 medium- and small-scale feedmills, and many small workshops have been established (Qian, 1994). In 1995, around 7.6 million mt of fish feed (mainly from imported supply) was produced and by the year 2000, 19 million mt will be required to meet the projected increase in production (Anon., 1997). (Estimates of future compound feed requirements vary--see Section 2.2, *Aquafeeds and Feeding Strategies*.)

For small-scale farmers of shrimp, eels, and mandarin fish, and other farmers producing high-value species, fluctuations in cost, supply and quality of fry, costs of increased feed, medication and other inputs, price fluctuations of end products and standards for high-quality export products, have increased investment risk. The government's encouragement of private investment and formation of joint ventures with foreign companies will continue to improve technology transfer and reduce some of these risks (Qian, 1994; Anon., 1996).

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3.1.2 East Asia

Japan, Democratic People's Republic of Korea; Republic of Korea; China, SAR of Hong Kong; Taiwan Province of China

Bartley, D.

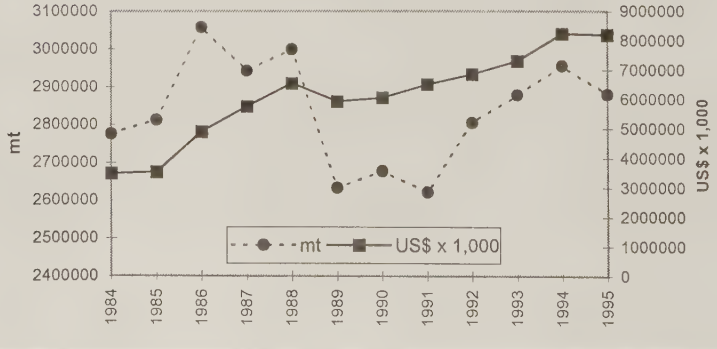
Production and production trends

East Asia contributed 11.7% and 24.4% of total Asian aquaculture production in terms of quantity and value, respectively, in 1995. Since 1984, production quantity has increased at a low APR of 0.4, or from 2.81 million mt to 2.93 million mt, while value has increased from US$3.73 million to US$8.50 million at an APR of 8.1 (Figure 3.1.2.1). Total production quantity in 1995 decreased by 3.3% from 3.03 million mt in 1994. The fall in the late 1980s was due in a large part to reductions in Taiwan Province of China [Taiwan (PC)]and the Democratic People's Republic of Korea (DPR Korea).

Capture fisheries (including aquatic plants) in the sub-region have declined at an average annual rate of 3.3% since 1984, from 16.25 million mt to 11.27 million mt in 1995. Aquaculture (including plants) accounted for 20.6% of total fishery production in 1995, up from 14.8% in 1984.

Fish and fishery products are extremely important in the sub-region, with per caput supply for Japan at 67.8 kg, the proportion of fish protein in total protein intake being 26% in 1993 (the last year for which data are available). Fish availability per caput in the Republic of Korea and DPR Korea was 52.3kg and 43.6 kg, respectively, and in China, SAR of Hong Kong (referred to as Hong Kong in figures) was 57.9 kg. The percentage of total protein accounted for by fish and fishery products was 18.7%, 18.4% and 16.5 % for China, SAR of Hong Kong, Republic of Korea, and DPR Korea, respectively. These figures are all above the global averages for per caput fish and fishery product availability of 13.4 kg and percentage of fish protein in total protein of 5.6%. The figures are also well above Asian averages of 13.9 kg per caput and 6.7%. However, DPR Korea is currently facing a severe food shortage and fish consumption may have changed substantially as a result.

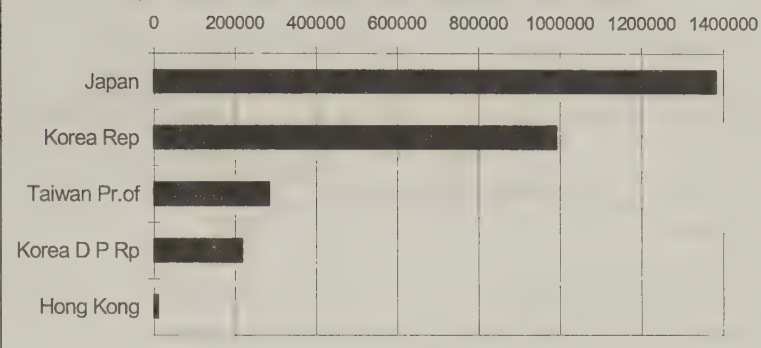
Figure 3.1.2.1. Aquaculture production trends in East Asia, 1984-1995



Japan and the Republic of Korea have held top positions in production in the sub-region since 1984; their 1995 proportion of sub-regional production being 48% and

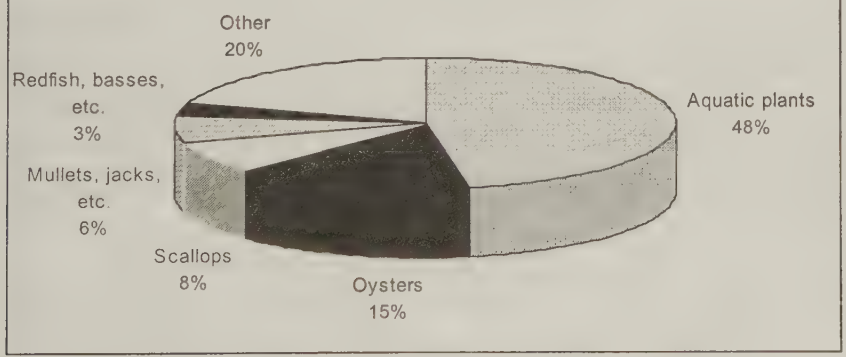
34%, respectively. Production from DPR Korea declined from 656,000 mt in 1984 to 216,000 mt in 1995. Taiwan (PC) accounted for 9.8%, DPR Korea 7.5%, and China, SAR of Hong Kong 0.3% (Figure 3.1.2.2). Growth of aquaculture production by quantity was slow in the region with Japan and Taiwan (PC) annually increasing at just over 1%, and the Republic of Korea at 3.6%. Production in China, SAR of Hong Kong was fairly static at a 0.2% increase per year and DPR Korea had an average annual rate of decrease of 9.6%. Production value increased between 7% and 9% per year for Japan, Taiwan (PC), and China, SAR of Hong Kong, whereas in the Republic of Korea, value increased by an average 12.7% per year. In DPR Korea, value decreased at a rate of 1.6% per year. These value figures do not take inflation into account.

Figure 3.1.2.2. Aquaculture production in East Asia (mt, 1995)



Forty-seven percent (1.36 million mt) of production in the sub-region in 1995 came from aquatic plants (Figure 3.1.2.3). Of the remaining tonnage, production was dominated by molluscs (58%) and marine fishes (19%). Diadromous fishes, freshwater fishes and crustaceans accounted for 12%, 8% and 3%, respectively. Production by species group is shown in Figure 3.1.2.4. Brown algae production decreased at an APR of 3.5 from 1984, whereas red algae production increased at an APR of 1.5. Oyster production decreased , with an APR of -0.9. The other major groups cultured--scallops, jacks, redfish, mussels and diadromous fishes--all showed positive APRs of 10.8, 1.2, 11.1, 10.1 and 8.3, respectively.

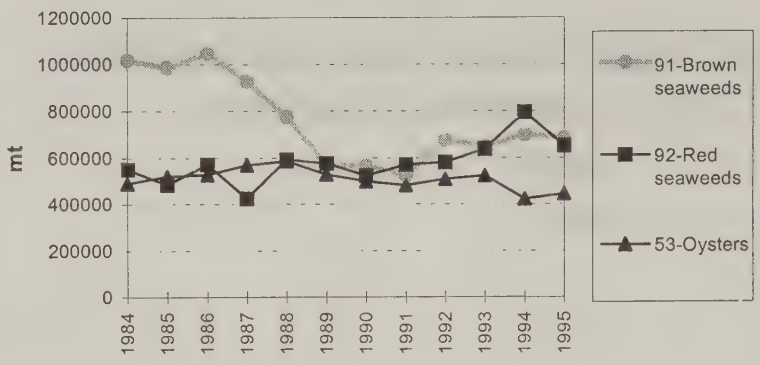
Figure 3.1.2.3. Relative production of main cultured species groups in East Asia (1995)



Major animal species cultured in terms of value were Japanese amberjack (*Seriola quinqueradiata),* silver seabream (*Pagrus major)*, Pacific cupped oyster (*Crassostrea gigas)*, eels (*Anquilla japonica* and *A.* spp.), and Yesso scallop (*Pecten yessoensis),* which made up 15%, 10%, 8%, 13% and 5% of the value, respectively.

The principle animal species in terms of production and their APRs over the period were the Pacific cupped oyster (-0.9), Yesso scallop (10.8), Japanese amberjack (1.0), Korean mussel (*Mytilus crassitesta*) (10.1), silver seabream (9.6), and milkfish (*Chanos chanos)* (6.8), for which 1995 rounded production figures were 444,000 mt, 228,000 mt, 170,000 mt, 75,000 mt, 72,000 mt, and 63,000 mt, respectively. Other high-value species, such as bastard halibut

Figure 3.1.2.4. Trends in production of main cultured species groups in East Asia



(*Paralichthys olivaceous*), coho salmon (*Oncorhynchus kisutch*), barramundi (*Lates calcarifer*) and giant river prawn (*Macrobrachium rosenbergii*), had high APRs of 28.8, 9.4, 52.5, and 18.4, respectively. Tilapias and eels (river and Japanese eels) had negative growth from 1984 to 1995, with APRs of about -1.5 and -2.4, respectively.

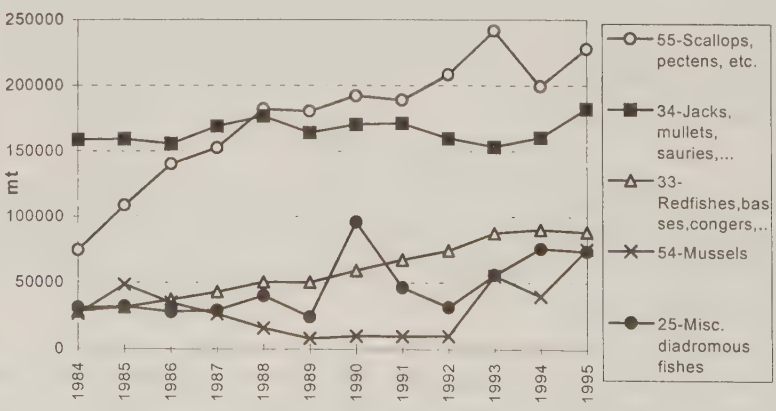
Production increased most for brackishwater aquaculture systems, with an APR of 5.5 from 1984 to 1995, whereas marine and freshwater aquaculture increased modestly at APRs of 0.2 and 0.3, respectively. The annual value of coastal aquaculture (including marine and coastal brackishwater systems) increased from US$2.57 billion in 1984 to US$6.19 billion in 1995 (APR of 8.3); that of inland aquaculture products increased from US$916 million to US$2.01 billion at an APR of 7.4.

Marine algae were the top valued species in 1995, with red and brown seaweeds accounting for 17% and 5% of the total value, respectively. The contributions of other species groups were: jacks, mullets, etc. 16%; river eels 13%; redfish, basses and congers 12%; oysters 8%; salmonids 5%; and scallops 5%.

Main issues

The sub-region is composed mostly of developed areas except DPR Korea. DPR Korea is facing a severe food shortage with the potential for mass starvation. Immediate food aid to this country will probably have a higher priority at present than fishery or aquaculture development. In the developed countries, marine and diadromous fish play a major role in the aquaculture sector.

Figure 3.1.2.4 (cont.)



However, there is competition for resources, and development is constrained in some areas, e.g. Japan and China, SAR of Hong Kong, by lack of available land. Due to the recent ratification of the UN Law of the Sea, Japan has lost access to many foreign fishing grounds that are now under local jurisdiction. Therefore, Japan has embarked on a large-scale fishery enhancement programme that includes coastal aquaculture, artificial reefs and marine ranching (Fujiya, 1996; Matsuoka, 1996). Such large-scale enhancements, supported by cooperatives between

government and industry, are being assessed for application in the region, e.g. in the Republic of Korea. Aquaculture in the region involves many high-value marine species that have high protein requirements. Thus, aquaculture is often an activity that is a net consumer of fish products in the form of diets high in fish protein (fishmeal). Efforts are underway to find replacements for fishmeal in aquafeeds, as well as to find alternate species that have good market appeal, but do not require excessive levels of fish protein in their diets (Watanabe and Kiron, 1997; see also section 2.1, *Aquafeeds and Feeding Strategies*).

Outlook

Fish and fishery products are extremely important and contribute a large proportion of the diet of the people in the sub-region. This will undoubtedly continue in many areas as governments such as of Japan are actively promoting and subsidizing aquaculture development, including an expansion of marine enhancement programmes. Japan is currently conducting research on breeding and culture of over 70 marine species, some of which will be suitable candidates for aquaculture and stocking. Culture of Japanese amberjack and Japanese eel is currently based on wild-caught broodstock and fry. There is also an expanding live food-fish market, especially in China, SAR of Hong Kong and Taiwan (PC), that imports wild-caught reef fishes, e.g. groupers and wrasses, from areas near the Philippines and Indonesia. The collection of these live fish is often very destructive, involving sodium cyanide that kills non-targeted fish, invertebrates and the coral itself. Research on breeding and aquaculture of these coral reef fish is ongoing in Taiwan (PC) and may alleviate some of the pressure on wild stocks. The outlook for the DPR Korea is less clear and will depend on the alleviation of the present food crisis.

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3.1.3 Southeast Asia

Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Viet Nam

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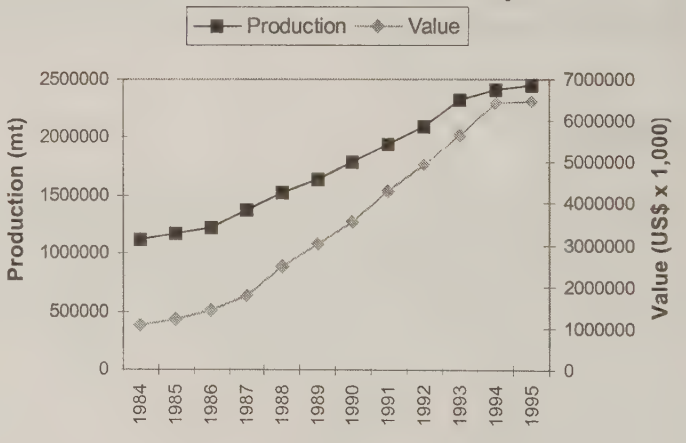
Production and production trends

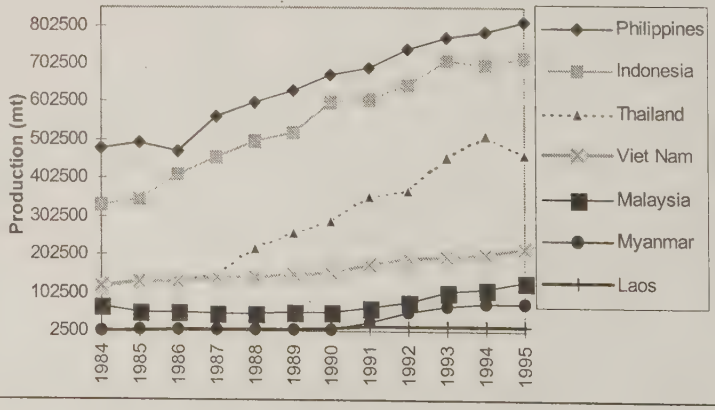
Total aquaculture production in Southeast Asia increased from 1.12 million mt in 1984 to 2.45 million mt in 1995. The increase has been steady since 1984 with a distinct increase in the average rate of production in 1987 which continued until 1994 at an APR of 8.4. Production by weight in the sub-region increased by only 1.5% in 1995 (Figure 3.1.3.1), mainly as a result of decreased production in Thailand that year of approximately 10% (Figure 3.1.3.2). The total value of aquaculture within this sub-region increased from US$1.06 thousand million in 1984 to US$6.47 thousand million in 1995, with an APR of 17.9.

Figure 3.1.3.1. Aquaculture production trends: Southeast Asia



Southeast Asia's contribution to global aquaculture production in 1995 was 8.8% by weight and 15.3% by value. It's share of total fisheries production by weight increased from 12.6% in 1984 to 17.7% in 1995. Within this sub-region, the Philippines continues to dominate production and in 1995 contributed 33.2% of the total by weight (Figure 3.1.3.2). Indonesia, Thailand, Viet Nam, Malaysia and Myanmar contributed 29.4%, 18.9%, 9.0%, 5.4%, and 3.0% by weight, respectively. However, in terms of value, Thailand ranked first in 1995 with a share of 29.3%, while Indonesia and the Philippines accounted for 28.8% and 19.6%, respectively. To a large extent, the relative production of high-value species such as penaeid shrimp

Figure 3.1.3.2. Aquaculture production trends in major Southeast Asian countries

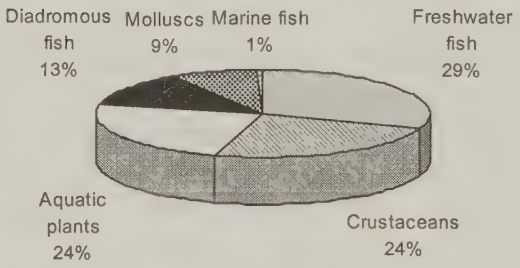


[1] Network of Aquaculture Centres in Asia-Pacific (NACA)

accounts for these differences in the countries mentioned. Between 1984 and 1994, Thailand witnessed the highest growth, with a 4.6- and 17.3-fold increase in production by weight and by value, respectively.

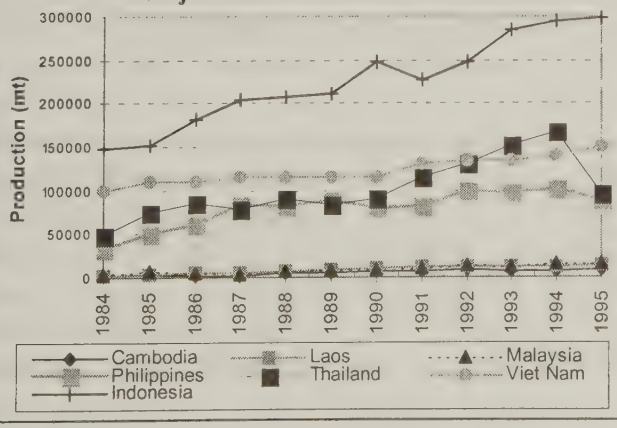
Aquaculture plays a significant role in local food fish production and animal protein consumption in most countries in this sub-region. The contribution of fish to total animal protein consumption in Indonesia and the Philippines was over 50% (53.5% and 51.5%, respectively) in 1993 (Laureti, 1996); in Thailand, Cambodia and Viet Nam, this contribution was more than 35%, and in others varied between 11.1% and 23.6% for the same year. The share of fish within animal protein consumption decreased in many countries in the sub-region from 1984 to 1993; for example, in Brunei Darussalam from 28.9% to 11.1%; Malaysia from 39.8% to 21.6%; Philippines from 61.3% to 51.5%; there were declines also in Cambodia and Laos. Only Thailand and Indonesia had a notable increase in per caput fish consumption in the sub-region during 1984 to 1993 (from 20.7 kg to 26.5 kg, and from 13.3 kg to 16.0 kg, respectively). All other countries demonstrated a gradual reduction in per caput fish consumption during the same period; e.g., Brunei Darussalam from 47.5 kg to 20.4 kg; Malaysia from 40.4 kg to 29.0 kg (Laureti, 1996).

Figure 3.1.3.3. Aquaculture production (by weight) in Southeast Asia: majorspecies groups in 1995



Although freshwater fish dominate Southeast Asian aquaculture production (29% by weight and 57% by value in 1995), the sub-region also produces considerable quantities of other important species groups, including crustaceans (24% by weight and 30% by value in 1995) and aquatic plants (24% by weight and 10% by value in 1995) (Figure 3.1.3.3). Diadromous fish and molluscs contributed 13% and 9% by weight, respectively. The contribution of marine finfish species to aquaculture was only 1% in 1995. Freshwater fish production increased gradually by 137% from 1984 to 1994 at an APR of 9.0, and slightly decreased (by approximately 10%) during 1995 (Figure 3.1.3.4). In contrast, crustacean production increased by 508% between 1984 and 1995, with an APR of 17.8. Diadromous fish demonstrated a continuous reduction in production since 1992, possibly reflecting the decrease in milkfish (*Chanos chanos*) production in the Philippines. All other species groups showed an increase in production during the period under review (Figure 3.1.3.5).

Figure 3.1.3.4. Freshwater fish production in major Southeast Asian countries

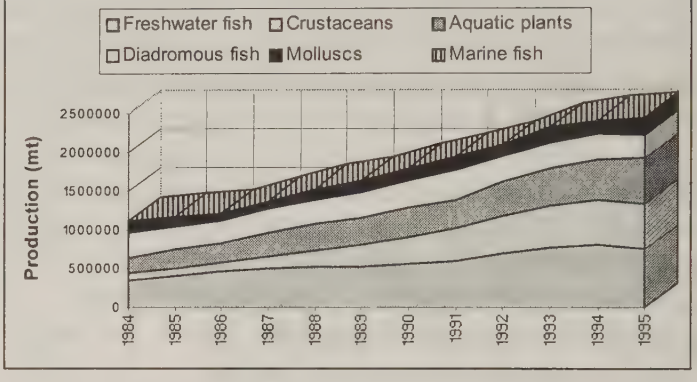


Indonesia ranks first in Southeast Asia in terms of freshwater fish production (0.3 million mt in 1995). Viet Nam, Thailand, and the Philippines rank next in the list, producing 0.15, 0.1, and 0.09 million mt in 1995, respectively. However, Thailand's freshwater fish production in 1995 decreased from 1994; 0.17 to 0.10 million mt, reflecting a general

reduction in the production of all species, including carps, catfishes, snakeheads and tilapias. This may have been due to the heavy floods which occurred in Thailand in 1995. The Philippines also recorded a decline in freshwater fish production in 1995, including tilapias and cyprinids, perhaps owing to the reduced aquaculture activity in Laguna de Bay, a major site of aquaculture production.

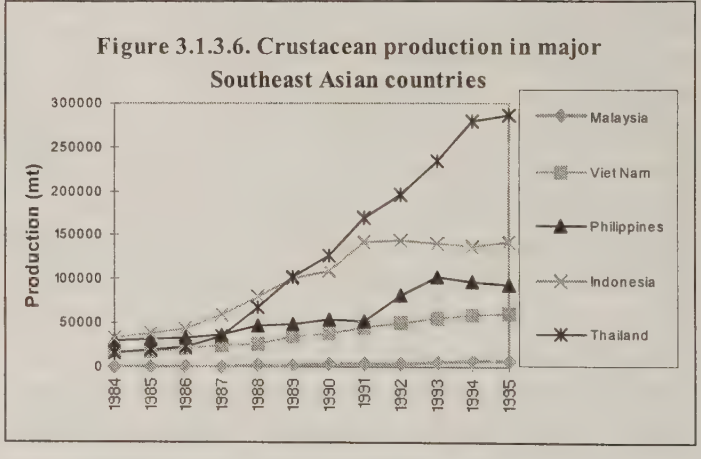
Production of aquatic plants in this sub-region increased considerably from 1984 to 1995, from 0.2 to 0.6 million mt by weight and US$304.2 million to US$627.0 million by value. These figures reflect the expanding red seaweed production in Indonesia, *Eucheuma* spp. production in the Philippines, and *Gracilaria* spp. production in Viet Nam. By contrast, diadromous fish production (milkfish, in particular) in this sub-region has been in a state of gradual decline since 1992 (0.23 million mt in 1991 to 0.13 million mt in 1995 in the Philippines alone). Although marine fish contribute little to Southeast Asian aquaculture production, the culture of certain species such as groupers (*Epinephelus* spp.) increased significantly during 1994-95. Production of the diadromous species barramundi (*Lates calcarifer*) also increased during the same period.

Figure 3.1.3.5. Aquaculture production trends in Southeast Asia: major species groups



Crustacean production in Southeast Asia is dominated by penaeid shrimp, especially the giant tiger prawn, *Penaeus monodon*. In 1995, the sub-region produced 0.48 million mt of *P. monodon*, 96.4% share of the total world production. Other crustacean species cultured include *P. merguiensis, P. indicus, Metapenaeus* spp., *Macrobrachium rosenbergii*, and a few species of crabs. Total crustacean production in the sub-region increased (with some fluctuation) within all major producing countries from 1984 to 1994 (Figure 3.1.3.6); the highest APR for crustaceans was recorded by Thailand (33.0). In Indonesia, crustacean production has stagnated at around 140,000 mt since 1991 (with little fluctuation). The production of Thai crustaceans decreased by 2.1% during 1994-1995, owing to the recent shrimp viral disease outbreak, SEMBV, which significantly affected production in the entire Asian region (Flegel, 1996). The reduction in crustacean production in the Philippines can also be attributed to disease. It is doubtful that the epizootic viral disease SEMBV has reached the Philippines; the production losses are reported to be due mainly to luminous vibriosis caused by *Vibrio harveyi* (Lavilla-Pitogo, 1996). Although the sub-region has suffered from serious disease-related losses to the shrimp sector over the past four years, there has been a small increase in total production, possibly due to successful intensification of culture practices; nevertheless, this may reflect an increase of farming areas in certain countries.

Figure 3.1.3.6. Crustacean production in major Southeast Asian countries



The share of Southeast Asia in global crustacean production by weight in 1995 was 52.5%. Compared with 1984, this reflects an increase of about 10.5%. However, the contribution of crustaceans to the total value of aquaculture production in Southeast Asia decreased slightly from 27.3% in 1984 to 26.5% in 1995. Apart from shrimp, considerable production of crabs (*Scylla serrata*) has been reported from the Philippines. This production has been increasing steadily from 1984 (833 mt) to 1993 (6,000 mt), although it decreased to 3,000 mt in 1995. There is also a small quantity of crabs produced in Malaysia, Indonesia, Thailand and Viet Nam. The only country reporting lobster production (*Panulirus* spp.) is Singapore (51 mt in 1995). Production of giant freshwater prawns has declined in the sub-region; Thailand remains the biggest producer (5,000 mt in 1995).

Total mollusc production in Southeast Asia increased from 0.14 million mt in 1984 to 0.21 million mt in 1995. The highest producer in 1995 was Malaysia with 0.10 million mt. Mollusc production in Malaysia and Thailand increased gradually over the past decade (with slight fluctuations), while in the Philippines there was a reduction between 1993 and 1995. Production of molluscs in Singapore also has been on the increase (526 mt in 1984 vs. 2,500 mt in 1995), although its share of sub-regional production is small. The major species produced in these countries are blood cockle (*Anadara granosa*), brown mussel (*Mytilus viridis*), green mussel (*M. smaragdinus*), Philippine cupped oyster (*Crassostrea iredalei*), and other oysters (*Crassostrea* spp.).

Main issues

Aquaculture in many Southeast Asian countries is dominated by finfish species feeding low in the food chain, such as milkfish, carps and tilapias, although some countries of the sub-region (Brunei Darussalam, Indonesia, Malaysia, Singapore and Thailand) culture increasing amounts of high-value carnivorous fish. Shrimp, *P. monodon* in particular, provide a significant contribution to the total value of aquaculture production in this sub-region. The production of aquatic plants and molluscs has also increased over the past decade. Although the rate of increase of freshwater fish culture has declined over the past few years, marine finfish culture and production of high-value species appear to have commenced in many countries.

Thailand became the world's top producer of cultured shrimp in 1991 by adopting appropriate culture systems. This has also been due to its suitable climatic conditions, soil and water temperature, availability of wild broodstock, long experience in aquaculture, seafood processing and trade, good infrastructure and transport facilities, and locally produced farm equipment and feeds (Kongkeo, 1994).

However, shrimp culture in the sub-region, including Thailand, continues to face considerable problems from disease. Recent emergence of viral diseases, such as Monodon baculo virus disease (MBV), Yellow-head virus disease (YHV), and systemic ectodermal and mesodermal baculo virus (SEMBV), which have spread through the sub-region in epizootic levels, has caused severe economic damage to the sector (see Section 2.2, *Fish Health and Quarantine*). Unregulated and unplanned expansion, resulting in environmental problems such as self-pollution of water supplies, is said to have contributed to this calamity; introduction of exotic pathogens through unregulated transboundary movement of broodstock and post-larvae may also have contributed to the problem (Subasinghe et al., 1996).

As diseases are becoming a major constraint to penaeid shrimp production in the sub-region, control strategies are also emerging and significant research has been undertaken by both the

state and the private sector. New and appropriate water management systems to minimize contact between cultured shrimp and exotic vectors and pathogens have been developed with considerable success (Flegel, 1996). In addition, new assays from genetic engineering using nucleic acid probes are evolving; the recent development of a polymerase chain reaction process for the detection of SEMBV (Wongteerasupaya et. al., 1996) can be considered as a major breakthrough in combating viral epizootics in penaeid shrimp culture. It is also important to note that investments from the private sector are now being made for research undertaken by reputed research establishments, which is an encouraging trend.

The environmental impact of shrimp culture remains a controversial area and trade concerns are being increasingly raised. This has led to further promotion by sub-regional countries of environmentally friendly farming techniques, with considerable attempts being made within the Association of Southeast Asian Nations (ASEAN) to harmonize farm management practices (Pawaputanon, 1997). However, it is likely that new strategies may be required to integrate shrimp farming into coastal management planning for balanced allocation of land resources. Fortunately, aquaculture development in Southeast Asia is receiving increasing attention within the context of coastal planning and management (Barg, 1992; Phillips, 1995; FAO/NACA, 1995) and environmental management of inland aquaculture has also been duly considered (Muir, 1992). Efforts have been made to develop approaches for planning for multiple resource-use objectives, while satisfying short-term financial and economic criteria as well as longer-term sustainability goals of the sub-region. Institutional support and policy may further evolve to include such issues, particularly in coastal areas receiving pressure from diverse developments in various sectors.

One of the critical constraints for overall, resource-based aquaculture development and environmental management in the sub-region has been the lack of policy frameworks to integrate the sectors concerned. The underlying need for such rational and uniform cross-sectoral approaches for aquaculture development in Southeast Asia has highlighted the importance of economic criteria in terms of conventional resource allocation decisions, and has raised questions concerning economic instruments for pollution control (and natural resource management), including licensing procedures, loading-related charges, and environmental recovery taxes (Barg, 1992; Van Houtte, 1994).

Another constraint to planning and sustainable development in aquaculture is inadequate knowledge concerning potential areas for development or expansion (Chua, 1992). The development of a system and procedures for regulating and monitoring provides an ideal opportunity to develop a strategic approach to managing the marine coastal environment, thus providing opportunities for sustainable expansion and development of coastal and marine aquaculture in the sub-region.

Recent shrimp culture problems have also led to an increasing interest in diversification of aquaculture in the sub-region, e.g. in marine and brackishwater fish species, particularly high-value species such as *Epinephelus* spp., *L. calcarifer*, and other coral reef associated species, mainly as export items to neighbouring areas such as Hong Kong. In fact, some sectors view aquaculture of such species as a means of taking pressure off threatened wild stocks (Johannes and Riepen, 1997). The major concern is the lack of consistently successful hatchery and nursery techniques for major species, and the possible decline of the resource base. However, several groups are now actively researching in this area and some countries are even looking into offshore cage culture of some of these high-value species (Dahle, 1995).

Maintaining the hygienic quality of products from aquaculture for international markets is becoming an important issue. Efforts are underway within the ASEAN region to include practices needed to improve food hygiene, including the adoption of the hazard analysis of critical control points (HACCP) concept from aquaculture production to processing (Surawanrangsi et. al., 1997).

Aquaculture will continue to play an increasingly important role in food security planning in many countries in the Southeast Asian region, with policies evolving in several countries to address the anticipated short-fall in fishery products from capture fisheries. In less-developed countries of the sub-region such as Viet Nam, Laos and Cambodia, greater emphasis is given to fish production for food security and rural development, as the governments promote aquaculture as a mean of poverty alleviation and food supply in many rural areas. This is clearly reflected in the continued increase in production of freshwater fish in these countries. Recent experiences in Viet Nam suggest that aquaculture in rural areas can promote rural development, food security, and women's participation in development. Such efforts need to be further strengthened (FAO/NACA, in press). Increased use of fish for direct human consumption rather than conversion to fishmeal or direct feeding to carnivorous marine fish is also an issue which has gained interest in the sub-region.

Outlook

Management practices for shrimp farming to deal with disease and environmental problems are likely to develop further. Considering the difficulties that the sub-region has faced over the past few years, slower expansion of shrimp culture is anticipated in most countries. Thailand, for example, has a policy for no expansion of farming into new areas. International trading concerns may also be an additional spur to enhance environmental management of shrimp culture. There may be foci on management policies, legislative frameworks, institutional support for better integration of aquaculture into coastal areas and reduction of environmental impacts. Resolution of such problems through improved farm management practices and better coastal management policies could lead to slower but continued, and probably more sustainable, growth in shrimp culture, and a better platform for growth in other aquaculture species (Subasinghe and Barg, in press).

Freshwater fish production will likely see continued growth in most countries in the sub-region. Aquaculture as a contribution to food security and rural development will become more important in some countries, especially less developed countries of the sub-region. Such efforts are likely to be supported by development agencies, and will possibly receive increased support in government policy planning and development as concerns and awareness over future fish supplies increase. More attention is likely to be given to the potentially important role of aquaculture as a contributor to rural development.

Diversification will continue to take place within marine finfish culture. The trend towards producing high-value species will increase, and even accelerate if hatchery problems can be overcome. This trend will lead to an increased focus on development of effective, yet economic feeds, in particular feeds with lower fishmeal content. This type of development trend may even require some new technologies such as offshore cages, although economic viability of such interventions will remain a question. Research efforts are likely to continue in these areas. Furthermore, mangrove crab culture may increase considerably if hatchery constraints can be overcome. Other species are also likely to be investigated. In freshwater, several new indigenous

species may be bred, especially in the Mekong area, as countries are showing an interest in development of culture of indigenous freshwater species.

The demand for processed products will increase as consumers, especially those from more developed countries, become more affluent. The demand for certain processed products can be met partly by the conversion of raw fish protein material into products with similar characteristics. For example, the product from fish flesh extraction, known as surimi, is currently being used to make substitutes for crab meat. Such processing techniques will allow adjustments in demand and supply by converting low-priced species to high-priced products and hence reduce the importance of species characteristics (FAO, 1995).

Southeast Asian aquaculture will see continued growth and technological development, an increasing amount of which will be in the commercial sector. There is likely to be a substantial science and technology input; increased output will be associated with greater demand on resources and a far greater need to reconcile conflicting demands. While production of aquatic species for export markets is increasing, rural aquaculture for local markets will also be developed, although economic changes may reduce incentives for non-urban activities. Rice-fish culture and other forms of integrated aquaculture will become more important in less-developed countries, and local species will receive greater attention.

Institutional involvement will become increasingly specialized, e.g. scientific support, specialized training, monitoring and regulation, and in some cases may link with private-sector development to provide exportable services.

Since more than 13% of total production in the sub-region is used to produce fishmeal, oil and other non-food products, there may also be a possible shift from non-food to food uses. Although the technology for converting this raw material into products for human consumption is available, the cost effectiveness of such processes is questionable and does not seem to attract investments at present. Nevertheless, the demand for high quality fishmeal for aquaculture is increasing (Ahmad, 1995).

Overall, the future for aquaculture development in Southeast Asia is good and the sub-region will continue to produce all types of aquatic products, including plants. The sub-region will overcome its constraints for such development, especially the environmental concerns, by addressing common resource utilization concepts and probably acting as a group within the larger existing economic groupings.

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3.1.4 South Asia

Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka

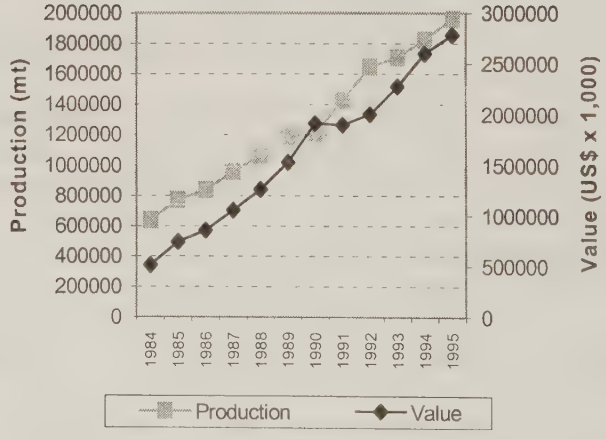
Subasinghe, R.

Production and production trends

In 1995, South Asia produced 1.96 million mt of aquatic animals and plants valued at US$2.79 thousand million, contributing 7.1% by weight and 6.6% by value to global aquaculture production. Production increased by 206.3% between 1984 and 1995 at an APR of 10.7, with India being the largest producer (1.61 million mt in 1995) within the sub-region (Figure 3.1.4.1). In contrast, total capture fisheries production in South Asia increased by only 42% from 3.59 million mt in 1984 to 5.1 million mt in 1995. The share of aquaculture in total fisheries production in South Asia increased significantly during the past decade from 15.2% in 1984 to 27.8% in 1995.

Aquaculture is of great importance to local food fish consumption in many countries in this sub-region. The share of fish protein in total animal protein consumption in Sri Lanka and Bangladesh in 1993 was high (51.5% and 46.7%, respectively), while that in India was relatively low (12.7%). The per caput fish consumption in South Asia in 1993 ranged from 0.2 kg (Bhutan) to 15.4 kg (Sri Lanka). There was no marked change in per caput fish consumption in the sub-regional countries during 1984 to 1993, except in Bangladesh, which increased its per caput fish consumption by 1.2 kg (from 7.6 kg in 1984 to 8.8 kg in 1993) within a decade (Laureti, 1996).

Figure 3.1.4.1. Aquaculture production trends: South Asia

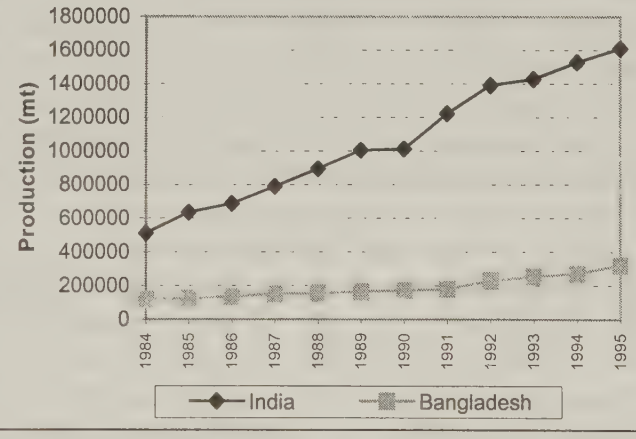


Over the past decade, the value of aquaculture products in South Asia increased from US$512 million in 1984 to US$2.79 thousand million in 1995 at an APR of 16.6. The aquaculture production trends in South Asia clearly reflect those of India, because India contributes 82.0% by weight and 76.8% by value to production from the sub-region. The reduced APR in India in 1990 possibly reflects the losses due to the exotic fish disease epizootic ulcerative syndrome (EUS), which affected a range of carps and other species (Roberts et. al., 1994) (Figure 3.1.4.2).

The contributions (by weight) of other countries in this sub-region in 1995 were: Bangladesh 16.4%; Pakistan 0.8%; Nepal 0.5%; and Sri Lanka 0.3%. However, the growth of aquaculture in these countries has been significant (except for Sri Lanka). During 1984 to 1995, production in Bangladesh, Pakistan and Nepal increased by 174.7%, 77.8%, and 396.6%, respectively. Following 89.3% growth of production from 1984 to 1989, Sri Lanka showed a clear stagnation in production at around 5,500 mt during 1990 to 1994. This was mainly owing to the change of government policy in Sri Lanka, removing state assistance to aquaculture, and this hampered the fingerling stocking programme carried out by the government. The policy changed again in 1994, and the resumption of state stocking programme led to a subsequent increase in production in 1995.

South Asian aquaculture production is dominated by freshwater fish (94.2% in 1995). The remainder is nearly all from brackishwater; production from the marine environment was insignificant (48 mt in 1995). Freshwater fish production increased from 0.62 million mt in 1984 to 1.83 million mt in 1995 at an APR of 10.3. Cyprinids are the main species cultured; they include mainly the Indian major carps *Labeo rohita, Catla catla,* and *Cirrhinus mrigala,* with smaller contributions from Chinese carps, common carp (*Cyprinus carpio*) and other minor carps. These fish are produced under both monoculture and polyculture in South Asia. Tilapia production in the sub-region has remained low with little fluctuation (3,000 mt in 1984 and in 1995). This could be due to the relatively low acceptability of tilapia as a food fish species in some countries in the sub-region. Diadromous fish production, which includes the culture of rainbow trout (*Oncorhynchus mykiss*) in India and Pakistan, totalled 1,200 mt in 1991. Since 1993 India has not reported any production of rainbow trout through aquaculture; production has thus declined to 20 mt from Pakistan. These figures do not take into account production from stocked natural or man-made lakes and other water bodies and floodplains, which are reflected in the FAO Inland Fisheries Statistics. The contribution of culture-based fisheries to food fish production in this sub-region is substantial.

Figure 3.1.4.2. Aquaculture production in key South Asian countries

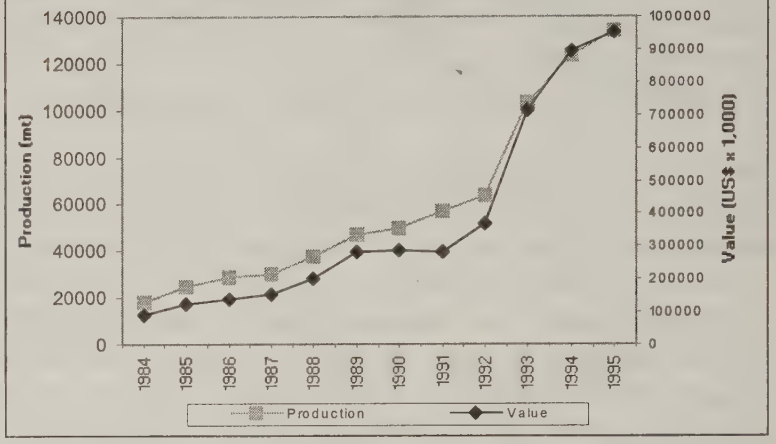


Crustacean aquaculture in South Asia is restricted to penaeid shrimp culture, except for a small amount of giant river prawn (*Macrobrachium rosenbergii*) production in Bangladesh (311 mt in 1994 and not reported in 1995). The total crustacean production in the South Asian sub-region increased from 18,000 mt in 1984 to 134,000 mt in 1995 (an increase of over seven fold). This growth occurred in two distinct phases (Figure 3.1.4.3)--from 1984 to 1992 (APR 16.9) and from 1992 to 1994 (APR 39.2)--as a result of increased production of penaeid shrimp in India, Bangladesh and Sri Lanka. In 1995, India, Bangladesh, Sri Lanka and Pakistan produced 97,000, 34,000, 3,000, and 48 mt of crustaceans, respectively. The value of total crustacean production in South Asia in 1995 was about US$953 million (34.2% of the total value of aquaculture in South Asia and 19.6% of the total crustacean production in South and Southeast Asia). However, there was a reduction in the total APR of crustaceans during

1994/95 (9.1), possibly a result of the shrimp viral disease outbreak in major producing countries, which created much concern about the future sustainability of shrimp culture in the sub-region (Kutty, 1997).

Marine finfish culture in South Asia is still in its infancy and at present does not contribute significantly to production. Although the Maldives has recently initiated some pilot-scale marine aquaculture programmes, no production has yet been reported to FAO.

Figure 3.1.4.3. Crustacean aquaculture in South Asia: production and value



Main issues

In South Asia, aquaculture production still comes mainly from extensive and traditional freshwater farming systems. Production originating from stocked lakes (man-made and natural) and floodplains also contributes significantly. As demand for fish is increasing rapidly, the countries are endeavouring to intensify freshwater fish production and to diversify aquaculture, while continuing traditional and extensive farming. To succeed, they require more advanced technology, trained and experienced manpower, and much-needed capital expenditure. Some countries are looking into integration of aquaculture with agriculture, and rice-cum-fish culture and other forms of integrated aquaculture are becoming important to the sub-region (FAO/NACA, 1995).

It appears that the freshwater aquaculture sector has been expanding at a considerable rate over the past decade. Over 75 species have been identified as potential candidates for aquaculture. However, only a few species are currently cultured commercially (Indian major carps, Chinese carps, and a very few indigenous species). Organized farming of other species on a commercial scale has yet to be developed and this appears to be a significant constraint to diversification of aquaculture in this sub-region (Ganapathy, 1996).

Bangladesh, as a unique country in the sub-region with substantial annual flooding, continues to endeavour to increase freshwater fish production through floodplain stocking. As mentioned, this activity is considered within the culture-based fisheries category in the FAO Inland Fisheries Statistics. However, the lack of adequate seed, and the inadequate disease prevention and control programmes appear to constrain the future development of this sector (Subasinghe and Hussain, 1997).

The prospects for marine culture are not promising. Unfortunately, the long coastlines of India and Sri Lanka offer little scope for seafarming due to openness of the coast and regular stormy conditions during the southwest (June-September) and northeast (October-December) monsoons, although there are large sheltered areas in India and some islands which may be suitable for mariculture (FAO/NACA, 1995).

In South Asia, shrimp are mainly produced for export markets and the main producers are India, Sri Lanka and Bangladesh. Environmental costs, social equity and sustainability have

become important issues in shrimp culture development in these countries. Besides the disease outbreaks which have devastated the industry since 1993, product quality, consumer acceptability and human health concerns have also emerged as major issues in the shrimp sector (Anon., 1997). The demand for quality aquaculture products is becoming highly significant in the developed countries. In order to continue and survive in a competitive world, the quality of shrimp produced in the sub-region will have to be improved.

Outlook

Aquaculture is growing rapidly and will continue to expand in this sub-region. It is unlikely that land and water will become limiting factors to the sectoral growth in most countries of the sub-region, although in some areas of India, freshwater availability may become a limiting factor. It will be interesting to see whether the sub-regional governments will give priority allocation of water and land to aquaculture over the next decade. As the sector grows, aquaculture diversification and intensification will become inevitable and a clear need for technological advancement for the commercial-scale farming of novel species will develop. Institutional involvement in aquaculture production and development will then be increased, and specialized scientific support, training, monitoring and regulation, etc., may slowly become linked to the private sector.

Although the availability of freshwater does not seem to be a limiting factor for future expansion of freshwater aquaculture, development of mariculture (particularly finfish) has commenced in countries where adequate and suitable marine water resources are available (such as India, Bangladesh, and Sri Lanka). This seems to contradict our view on the prospects for mariculture. The development of this sub-sector is being driven mainly by the demand for mariculture products in Southeast Asia, and this will create significant interest in developing appropriate technology and trained personnel to diversify the aquaculture sector in South Asia. Effective integrated coastal area management strategies will need to be adopted more widely and rigorously in order to avoid environmental drawbacks of marine and coastal aquaculture development, and to control impact from other non-aquaculture activities on environmental quality in coastal areas (Holmgren, 1994; FAO/NACA, 1995).

The future of the crustacean sub-sector (almost exclusively penaeid shrimp) will largely depend on whether or not national governments view shrimp culture as an environmentally friendly, sustainable, revenue-earning production sector with adequate social equity. Constitutional reforms; changes to existing legislative frameworks for aquaculture development; new policies for natural resource allocation, management and conservation; development of practical policies for privatization; etc., will have to take place in those countries wishing to see the sustainable development of shrimp culture (ADB/NACA, 1996). The issues of shrimp farm effluent management and pollution control will also have to be adequately addressed. Successful evolution of policies and strategies dealing with environmental issues, social equity and sustainability in shrimp aquaculture should lead to a more favourable climate for future coastal aquaculture development in general.

Future aquaculture development in South Asia will create a significant demand in developing hatchery technology and locally made artificial feed, and will help accelerate establishment and expansion of private sector aquaculture ventures. If large-scale, culture-based fishery development programmes with aquaculture inputs are to be successful in the long run, the socio-economic issues, such as land ownership, leasing procedures, common property rights, etc., need to be addressed and resolved adequately.

Overall, the outlook for aquaculture development in South Asia is good, as both commercial and subsistence farming continue to grow. However, The importance of future fish availability for food security and nutrition in highly populated countries in the sub-region such as India and Bangladesh, will be an issue to be monitored and addressed. Although aquaculture is expanding in the sub-region, it is timely to conduct a strategic survey and an evaluation of the contribution of aquaculture to poverty alleviation and rural development in these countries.

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3.1.5 West Asia

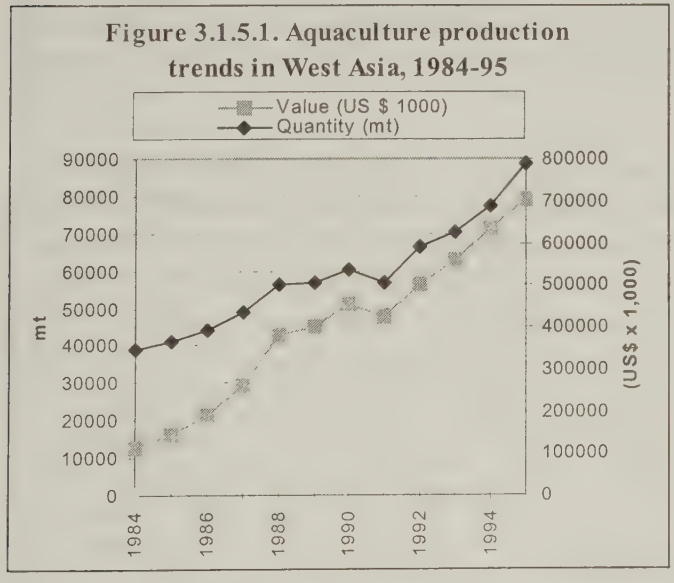
Afghanistan, Bahrain, Cyprus, Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Turkey, United Arab Emirates, Yemen.

Shehadeh, Z. H.

Production and production trends

Aquaculture is a fairly recent activity in this geographic area, contributing in 1995 a modest 0.4% and 2.0% of Asian aquaculture production by quantity and value, respectively. However, this masks the considerable importance of the sector in local production of food fish in some countries--77% of total production in Israel, 62% in Iraq and 48% in the Syrian Arab Republic. Since 1984, production has increased at an APR of 7.7, from 39,000 mt to 89,000 mt in 1995 (127% change). Production value grew at an APR of 18.1, from about US$113 million to US$704 million during the same period (Figure 3.1.5.1). Total production in 1995 increased by about 11,000 mt (14%) and US$70.7 million (11.2%) over 1994, compared to respective global increases of 10% by weight and 5.2% by value. By contrast, production from capture fisheries increased by 423,000 mt (42.4%) at an APR of 3.3 during 1984-95; landings in 1995 were up by 117,000 mt (9%) over 1994. The contribution of aquaculture to fish production in the region increased from 3.8% in 1984 to 5.8% in 1995.

Figure 3.1.5.1. Aquaculture production trends in West Asia, 1984-95



Ten of the 16 countries of the area report aquaculture production, with five accounting for 96% of the total quantity produced in 1995 (Figure 3.1.5.2). The Islamic Republic of Iran dominated production quantity, but its share decreased from 47% in 1984 to 32% in 1995, due to a relatively slower growth rate (APR 4.1), the second lowest among the main producers. Growth in production since 1984 has been dramatic in Saudi Arabia (APR 52.5), Turkey (APR 23) and Cyprus (APR 20), albeit from low initial values. As a result of the fast growth rate of the sector in Turkey, the country replaced Israel as the second largest producer as of 1994. Production has been static in Israel since 1988 (1984-95 APR 3), while in the Islamic Republic of Iran, the 1988 production level was exceeded only in 1995. In the Syrian Arab Republic, production is yet to exceed 1992 levels.

Production during 1984-95 was mainly from freshwater (100% in 1984; 88% in 1995) with an APR of about 7 over the period; in 1995, production was up 13% over 1994. During the period, production from brackishwater and marine environments increased from nil to 11% by

Figure 3.1.5.2. Main aquaculture producers in West Asia (1995)

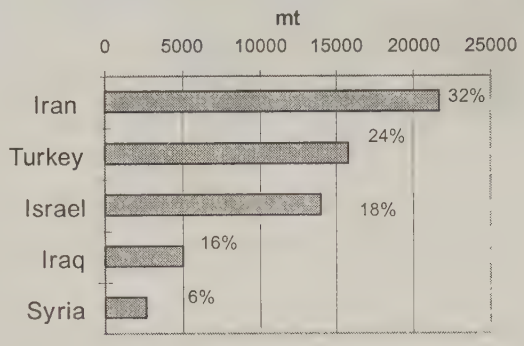
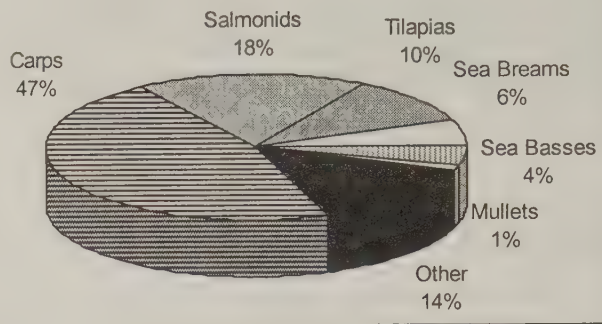


Figure 3.1.5.3. Relative production of main cultured species groups in West Asia (1995)



quantity and 20% by value (10,000 mt, US$135 million) in response to scarcity of freshwater and/or the lure of better profitability from high-value species.

Finfish account for almost the entire aquaculture output from the area, with freshwater finfish the main group produced throughout 1984-95 (APR 4.9). In 1995, finfish production (8,000 mt) was up about 11,000 mt (14%) over 1994. Cyprinids accounted for about 46.3% (41,000 mt) of production in 1995 (Figure 3.1.5.3), up 7.4% on 1994, with Israel, the Islamic Republic of Iran, Iraq and Syrian Arab Republic the main producers. Salmonids (trouts) contributed 18% (16,000 mt), up 67% on 1994 (due mainly to a reported sharp increase in Turkey), with Turkey as the main producer. Tilapias accounted for 10%, or about 9,000 mt (up 3.6% on 1994), mainly from Israel and Saudi Arabia. Concerning marine finfish, gilthead seabream (*Sparus auratus*) contributed 6% (5,000 mt), down 15% from 1995; Mediterranean seabass (*Dicentrarchus* spp.) 4% (4,000 mt), up 40% on 1994; and mullets (mainly *Mugil cephalus)* 1% (1,000 mt), up 39% on 1995, with Turkey as the main producer. Production of about 200 mt of marine shrimp, *Penaeus monodon* and *P. indicus,* was reported in 1995, almost exclusively from Saudi Arabia.

During 1984-95, carp production by weight grew at a modest APR of 4.4. Output in 1995 was 8% below peak production in 1988, due to a decrease in common carp and grass carp production (21% and 40%, respectively), in the main producing countries of Israel and Islamic Republic of Iran, attributed to market saturation (common carp and silver carp in Israel; Sarig, 1994; Mires, 1995; Sarig, 1995) and production problems in the Islamic Republic of Iran (disease outbreaks and poor survival of grass carp fingerlings, and poor growth of silver carp attributed to hybridization) (Figure 3.1.5.4a; FAO, 1992; Matinfar and Nikouyan, 1995). Tilapia production grew at an APR of 9 but declined sharply in 1992, due to cold weather in Israel (main producer), and recovered slowly to about 1991 levels by 1995 (Sarig, 1994; Mires, 1995; Figure 3.1.5.4b). Culture of trouts, mainly *Oncorhynchus mykiss,* has been increasing consistently over the period at an APR of 23. Production over 1,000 mt was first reported in 1990 for gilthead seabream, and in 1993 for Mediterranean seabass (3,000 mt) and increased by 370% and 8.5%, respectively, by 1995. Israel has been gradually increasing its production of these marine species, with production reaching nearly 1,000 mt in 1995.

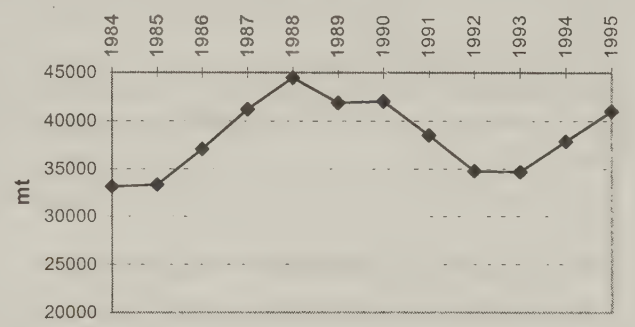
Production in the main producing countries is mainly in earthen ponds, with the exception of Turkey, where cages are used for culture of marine finfish, and Israel, where multi-purpose reservoirs accounted for about 46% of the surface area used for aquaculture in 1995 (Sarig, 1996). Polyculture systems predominate in the Islamic Republic of Iran, Israel and Iraq.

Aquaculture products are consumed locally, except in Turkey, where a large part of marine finfish production is exported to Italy, Greece and northern Europe.

Main issues

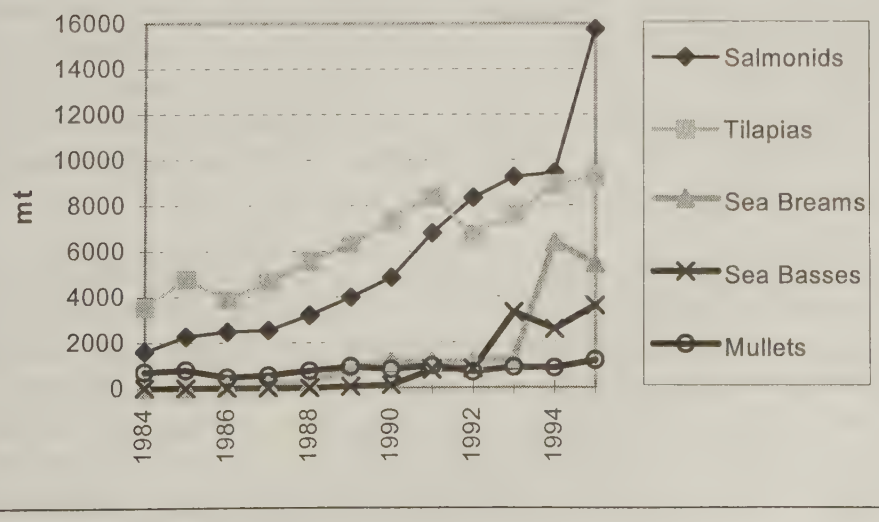
With the bulk of production coming from freshwater aquaculture, expansion of production is limited by the scarcity of freshwater due to the priority allocation of water and land to agriculture in most countries, or to competition with more profitable uses of available water resources (FAO 1992; Dr. I. Krouma (Syrian Arab Republic), personal communication). The restricted availability of freshwater is consequently influencing the type of production systems used in aquaculture and the approach to aquaculture development. This is most evident in Israel, where competition for water, combined with market factors, has resulted in an important shift from traditional shallow fish ponds to fish culture in multipurpose reservoirs, which have proven to be more productive than ponds (Sarig, 1996). In addition, use of intensive culture systems incorporating water recycling to reduce water use (mainly for tilapia culture) is increasing slowly, as is offshore cage culture of marine finfish.

Figure 3.1.5.4a. Trends in production of carps in West Asia



In the Islamic Republic of Iran, natural resource limitations have led to the concentration of freshwater aquaculture in the northern provinces where water supplies are less restricted; the focus of development efforts is on increasing productivity from existing farms, intensified enhancement of fisheries in the Caspian Sea, and fish stocking in reservoirs and inland waters (FAO, 1992). The country is also very actively developing coastal (brackishwater and marine) aquaculture (Nash, 1997). The Syrian Arab Republic is meeting the challenge in several ways: by using saline soils around irrigation systems, as a productive approach to desalinization of soils; improving carp production from cage culture in Lake Assad; integrating aquaculture with agriculture in the middle Euphrates basin, including fish culture in irrigation canals; and by developing cage culture of marine finfish (Kelleher, 1996; Lisac, 1996) .

Figure 3.1.5.4b. Trends in production of other main cultured groups in West Asia



Saudi Arabia, where freshwater supply is very limited, has been using intensive recycling systems for tilapia

production, often with irrigation water for agriculture, and has been experimenting with adapting technology for tilapia culture in seawater. It is also expanding shrimp culture along the Red Sea coast and is developing technologies for culture of selected marine finfish and shrimp (groupers, rabbitfish, *Penaeus indicus,* etc.) (Shehadeh, 1996; James et al., 1997).

Since aquaculture is a very recent activity in most countries of the region, institutional capacity is a limiting factor in some areas. Hence strengthening of institutional capacity, including human resources, supporting industries, extension services/access to information, improving capacity of farmers, transfer and adaptation of technology, etc. are priority development targets (Matinfar and Nikouyan, 1995; Shehadeh, 1996; IFRTO, 1997). These efforts will help to expand production in the future.

In Israel, market saturation has been observed for carps, which constitute more than half of the production from aquaculture, and consumer reaction to lower prices has been poor (Mires, 1995).

Outlook

As stated earlier, aquaculture is a major source of food fish in Israel, Syrian Arab Republic and Iraq, and is being developed to increase its contribution to food supplies as landings from capture fisheries level off. Other countries in the region, like the Islamic Republic of Iran and Saudi Arabia, where aquaculture is not of equal importance in food fish supplies at present, are also moving to develop aquaculture in anticipation of future stagnation of supplies from capture fisheries.

Production in Israel is projected to increase by about 13% in 1996, followed by a 5% annual increase to the year 2000; that is, an increase of 6,000 mt, or 38.4% over 1995 production. This will be coupled with efforts at species diversification and increasing production efficiency to reduce market price (Mires, 1995). The Islamic Republic of Iran has more ambitious plans, with a production target of 550,000 mt within 10 years (from 1996), or an increase of more than 1,800% over 1995 (29,000 mt), through expansion of areas under culture, improving productivity of existing farms and making maximum use of the country's water resources (IFRTO, 1997).

In general, expansion in freshwater aquaculture in the sub-region can be realized to various extents through areal expansion into areas unsuitable for agriculture; improvement of the productivity of existing farms; more intensive use of inland waters (e.g. cage and pen culture and culture-supported fisheries); and by integrated aquaculture-agriculture production systems, including fish culture in irrigation systems. As noted above, most of the countries in the region are already taking steps in these directions. The adoption of intersectoral co-ordination in the management of natural resources, coupled with promising market conditions, could facilitate the success of these initiatives in many countries of the region by ensuring access of the sector to these resources on a competitive basis.

Major increases in the production of shrimp can be expected in the mid term from Saudi Arabia and the Islamic Republic of Iran, as on-going large-scale development projects come into production. Increases in the production of gilthead seabream and Mediterranean seabass will depend on market development in Europe and expansion of domestic markets by reducing production cost and market price. Production of Mediterranean seabass may increase significantly in the mid term due to its wider acceptability in Europe, and as some technical problems in its production are resolved. Contributions from the farming of other local marine

finfish in the Mediterranean area, the Gulf and the Red Sea can be expected in the long term, as the results of current species diversification efforts in both areas bear fruit.

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3.2 Europe

Albania, Andorra, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Channel Islands, Croatia, Czech Republic, Denmark, Faeroe Islands, Finland, France, Germany, Gibraltar, Greece, Holy See, Hungary, Iceland, Ireland, Isle of Man, Italy, Liechtenstein, Luxembourg, Macedonia FYR, Malta, Monaco, Netherlands, Norway, Poland, Portugal, Romania, San Marino, Slovakia, Slovenia, Spain, Svalbard and Jan Mayen, Sweden, Switzerland, United Kingdom, Yugoslavia FR

Tacon, A. G. J.

Production and production trends

Total aquaculture production in this region in 1995 was 1.4 million mt, valued at US$3.8 billion. This represented 5.1% and 8.9% of total world aquaculture production by weight and value, respectively (Figure 3.2.1). Since 1984, aquaculture production increased by a modest 51.6% by weight and 165.2% by value; the total aquaculture production sector exhibiting an overall APR of 3.8 by weight and 9.3 by value from 1984 to 1995 (Figure 3.2.1), with production up 3.7% by weight and 5.6% by value since 1994. The slow growth of the aquaculture sector within the region, especially between the late 1980s and the early 1990s, was due to several factors, including the political and economic transition in eastern European countries and consequent decline in freshwater carp production, the drastic fall in mussel production in Spain due the increasing occurrence of red tides, and to a lesser extent due to the progressive saturation of the mollusc market in the region (FAO, 1996; Pedini, 1996; Szczerbowski, 1996).

In marked contrast to the aquaculture sector, total capture fisheries production (finfish, shellfish and aquatic plants) within the region has remained stagnant, decreasing from 12.6 million mt in 1984 to 12.3 million mt in 1995, with aquaculture's contribution toward total fisheries landings consequently increasing from 6.9% in 1984 to 10.3% in 1995. Despite the decrease in capture fisheries production, fish and fishery products play an important role in food supply, with total per caput food fish supply (live weight equivalent) within the region increasing from 16.9 kg or 8.2% of total animal protein intake in 1984 to 18.1 kg or 9.0% of total animal protein intake in 1993 (the last year for which data are available; Laureti, 1996). However, since information on aquaculture stocks and trade are not separately available within the FAO food balance sheets for fish and fishery products, it is not possible to ascertain the exact contribution of aquaculture products to total food fish supply and protein supply within the individual member countries of the region. Despite this, it can be seen from Table 3.2.1 that total food fish

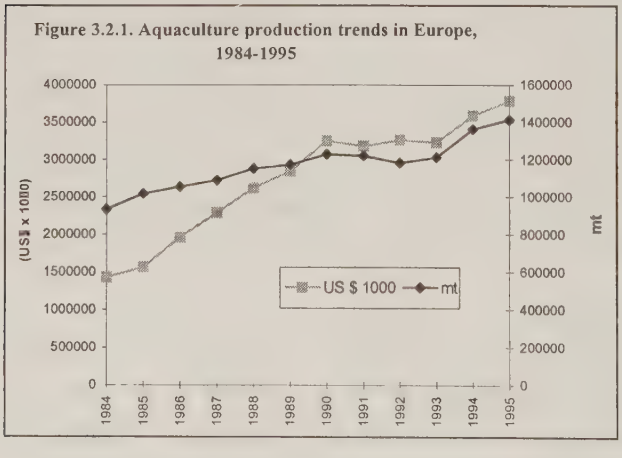
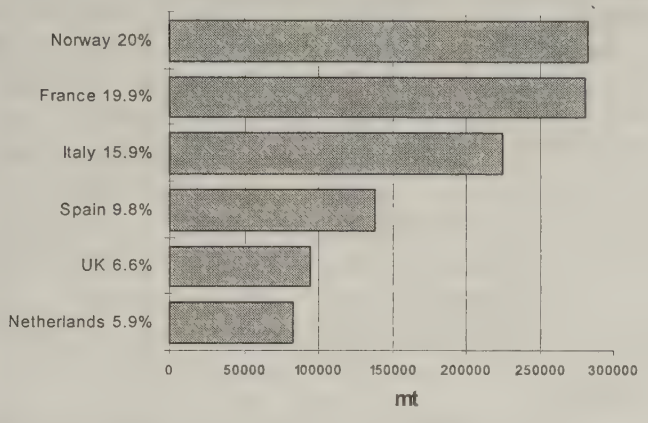


Figure 3.2.1. Aquaculture production trends in Europe, 1984-1995

supply was highest within the northern and western European countries, and lowest within the central and eastern European countries.

Figure 3.2.2. Main aquaculture producers in Europe, 1995



In 1995, only 31 of the 42 countries in the region reported aquaculture production, with the bulk of aquaculture production currently being in northern Europe (Norway) and the European Union (Figure 3.2.2). The top ten aquaculture countries in 1995 produced 90% of the total aquaculture production within the region (Table 3.2.2). With the exception of Spain and Portugal (where red tides and disease outbreaks, respectively, have had a negative effect on the growth of the mollusc aquaculture sector), aquaculture production in many central and eastern European countries in 1995 for which statistical data are available (e.g. Germany, Romania, Hungary, Bulgaria and Albania) have still not managed to surpass 1984 production levels. As with capture fisheries, the poor performance of the aquaculture sector within these countries has been mainly due to the political and economic upheavals (FAO, 1996).

Table 3.2.1. Per caput food fish supply (live weight equivalent) and contribution to animal protein supply in selected European countries in 1993 (Laureti, 1996)

Country	Per caput supply (kg)	Fish/animal proteins (%)
Highest		
Iceland	92.7	30.4
Faeroe Islands	88.1	52.6
Portugal	57.3	24.3
Norway	46.5	25.3
Spain	39.1	17.9
Finland	32.8	15.5
France	27.1	8.2
Lowest		
Hungary	3.9	2.3
Macedonia FYR	2.9	3.0
Bulgaria	2.4	1.7
Romania	1.9	1.7
Croatia	1.5	1.3
Bosnia &	1.6	2.1
Herzegovina	1.0	0.6
Albania	0.5	0.4
Slovakia		
Europe (average)	**18.1**	**9.0**

Aquaculture production in the region during 1984-1995 was mainly from coastal or brackishwaters and marine waters (70% in 1984; 76% in 1995). Production in this environment grew at an APR of 4.6, compared with 1.7 for freshwater or inland aquaculture. The total value of coastal aquaculture production increased at an average rate of 12.8% per year from US$708 million in 1984 (49.6% of total aquaculture) to US$2.7 thousand million in 1995 (70.7%), whereas the value of inland aquaculture products grew at an average rate of only 4.0% per year, from US$719 million in 1984 to US$1.1 thousand million in 1995.

The major aquaculture species groups cultured in the region in 1995 were finfish (779,000 mt) and molluscs (626,000 mt), with only a very limited production of aquatic plants (5,000 mt) and crustaceans (2,000 mt) (Figures 3.2.3 and 3.2.4). In marked contrast to finfish production, the production of molluscs has remained relatively static, growing at an average annual rate of only 0.3% by weight since 1984 (5.7% by value) and production decreasing by 4.2% since 1994 (although value increased by 7.2% over this period). The main mollusc species cultivated within the region are mussels (61.2% of the total,

Table 3.2.2. Top ten aquaculture producers in Europe in 1995

Country	Total production (mt)	Growth 84-95 (APR)	Value (US$ million)
Norway	282,471	24.3	1,037
France	280,785	3.5	663
Italy	224,865	7.9	499
Spain	138,260	-5.4	259
United Kingdom	93,838	16.4	265
Netherlands	83,285	3.0	67
Germany	58,264	-4.8	163
Denmark	42,205	5.4	137
Greece	32,644	26.3	157
Ireland	31,922	6.9	85

with the main species being the blue mussel (*Mytilus edulis)* and Mediterranean mussel (*M. galloprovincialis*)), oysters (25.5%; main species being the Pacific cupped oyster (*Crassostrea gigas)*) and clams (13.1%; main species being carpet shells, *Tapes* spp.). The main mollusc-producing countries within the region in 1995 were France (34.3% total molluscs), Italy (25.7%), Spain (17.1%), and the Netherlands (12.9%; Table 3.2.3). The total value of mollusc production in 1995 was US$907 million or 24.0% of total aquaculture production within the region.

By far the most important species groups cultured within the region are finfish, for which production increased at an APR of 8.3 by weight and 10.6 by value since 1984 (up 11.1% and 5.1% since 1994, respectively). Total finfish production in 1995 was valued at US$2.8 thousand million or 74.9% of the total value of aquaculture production within the region. The main finfish species groups cultivated in the region are salmonids (Table 3.2.4), with the total production in 1995 amounting to 614,000 mt (i.e. 78.9% of total finfish production) and valued at US$2.1 thousand million, or 56.1% of the total value of aquaculture products in 1995. Salmonids are mainly produced at high stocking densities in intensive cage-, tank- or pond-based farming systems in northern European (i.e. Norway) and European Union (EU) countries, with the two major cultivated species being the Atlantic salmon (*Salmo salar*) (valued at US$1.3 thousand million) and rainbow trout (*Oncorhynchus mykiss*) (valued at US$311 million). However, in contrast to the much older rainbow trout farming sector, which has grown by only a modest 75.1% since 1984 with an average APR of 5.2 (2.1% increase since 1994), farmed Atlantic salmon production has increased by a staggering 1,236% since 1984, with an APR of 26.6 (22.0% increase since 1994)! As a result of the spectacular growth in production of these species, it is perhaps not surprising that Europe accounted for 65.2% of the total global production of farmed salmonids in 1995.

Figure 3.2.3. Relative proportion of main cultured species groups in Europe (1995)

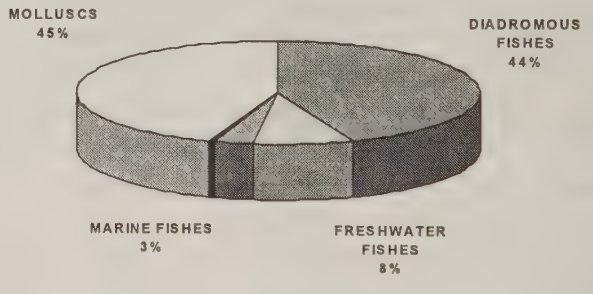
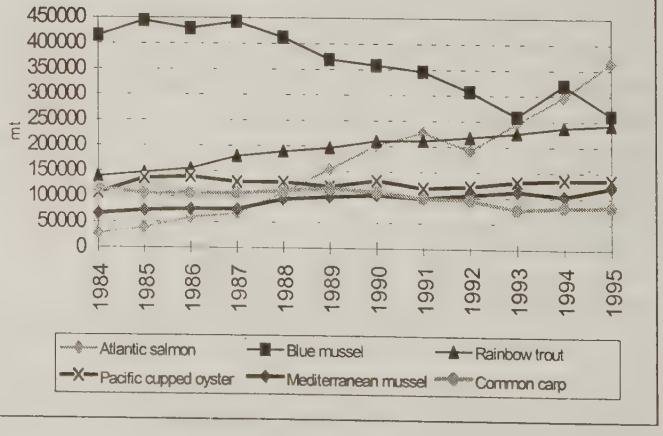


Figure 3.2.4. Trends in production of main cultured species in Europe



Freshwater cyprinids constitute the second major finfish species group cultivated in the region (13.6% of total finfish production in 1995), with total production valued at US$259 million (Table 3.2.4). In contrast to salmonids, these species are mainly produced at relatively low stocking densities in semi-intensive pond-based farming systems in eastern and central European countries, as a low-priced food fish for domestic consumption. The main cultivated species are common carp (*Cyprinus carpio*) and silver carp (*Hypophthalmichthys molitrix*). Production of cyprinids within the region has fallen by over 25% since 1984 from 142,000 mt to 106,000 mt in 1995, after reaching a high of 159,000 mt in 1989. As mentioned previously, this decrease was mainly due to the economic and social problems faced by the transition within the eastern European countries from centrally planned to market economies (Staykov, 1994; Szczerbowski, 1996).

Table 3.2.3. Major cultivated molluscs and producing countries in Europe in 1995

Species/Country	Total production (mt)
Mussels	**383,129**
Blue mussel	261,773
- Spain 35.2% total	
- Netherlands 30.3% total	
- France 18.8% total	
Mediterranean mussel	121,356
- Italy 78.3%	
Oysters	**159,622**
Cupped oyster	134,785
- France 96.7% total	
Clams/cockles	**82,025**
Clams/carpet shells	75,005
- Italy 80.2% total	
Total molluscs	**626,213**

The next largest finfish species group cultivated in the region was marine finfish (5.4% of total finfish production in 1995), with production valued at US$333 million. These high-value species are generally cultivated within intensive cage-, tank- or pond-based farming systems, in coastal waters of the warmer southern European/Mediterranean countries (i.e. Greece, Italy, etc.). The two major cultivated species are the gilthead seabream (*Sparus auratus*) and the European seabass (*Dicentrarchus labrax*) (Table 3.2.4). Although the industry is still very much in its infancy, production has increased rapidly, the two species displaying an APR of 42.1 (from 362 mt to 17,000 mt) and 43.6 (315 mt to 17,000 mt) from 1984 to 1995, respectively.

Main issues

The key issues facing aquaculture development in Europe can be broadly divided into two categories depending upon the farming strategy pursued: the intensive production of high-value species such as salmonids, marine finfish and molluscs within the EU and northern European countries, which are targeted toward luxury or niche markets; and the semi-intensive and extensive production of lower-value (in marketing terms) freshwater finfish such as cyprinids in central and eastern European countries, targeted toward the domestic market.

With regard to the intensive production of high-value species, the main issues facing the sector include: 1) over-production and saturation of markets within Europe for farmed salmon, seabass, seabream, mussels, and to a lesser extent oysters, and consequent decrease in fish prices and profitability (Pedini, 1996). For example, the Norwegian Fish Farmers Association has had to introduce harsh measures to avoid over-production and market saturation, including the mass destruction of Atlantic salmon smolts and the introduction of strict feed quota systems limiting the use of salmon feed by farmers (Anon., 1996); 2) current total dependence of intensive farming systems for salmonids, eels and marine finfish upon capture fisheries for sourcing their feed inputs (i.e. in their use of fishmeal, fish oil and other fishery by-products in compound aquafeeds) and the consequent urgent need for the sector to reduce this dependence by using alternative more sustainable dietary protein and lipid sources (Tacon and Barg, in press); 3)

decreased mollusc production within southern European countries due to the increasing occurrence of toxic red tides and consequent incidence of diarrhetic and paralytic shellfish poisoning, and to a lesser extent due to the increasing occurrence of parasitic diseases (Figueras et al., 1996; Martinez et al., 1996). For example, shellfish poisoning caused by red tides was responsible for the drastic drop in mussel production in Spain, from a high of 247,000 mt in 1986 to 90,000 mt in 1993; and 4) increasing competition with other users for available resources, including water and sites, coupled with growing public awareness about environmental issues and increasing pressure for "clean and green" aquatic food products (Muir, 1996; Rosenthal, 1997).

Table 3.2.4. Major cultivated finfish species groups and producing countries in 1995

Species group/Country	Total production (mt)
Salmonids	**614,354**
Atlantic salmon	363,107
- Norway 73.9%, UK 19.4%	
Rainbow trout	242,693
- France 20.2%, Denmark 16.9%, Italy 16.6%	
Cyprinids	**105,566**
Common carp	83,223
- Poland 23.7%, Czech Republic 23.1%, Germany 16.8%, Hungary 8.8%, Bulgaria 7.8%, France 6.0%, Romania 5.4%	
Silver carp	10,101
- Romania 76.2%, Hungary 11.1%, Bulgaria 10.8%	
Marine finfish	**41,870**
Gilthead seabream	17,254
- Greece 54.4%, Italy 18.0%, Spain 15.7%	
European seabass	16,901
- Greece 56.4%, Italy 21.3%, France 15.7%	

In most central and eastern European countries, the main issue faced by the aquaculture sector has been the drastic changes resulting from political-economic transition, which resulted in: 1) the collapse of state subsidies to the sector; 2) high inflation and interest rates within these countries, and the consequent lack of capital for the purchase of inputs, including fish feeds; 3) the loss of traditional markets for selling their subsidized aquaculture production (within the former USSR area and domestically); and 4) adverse weather conditions in central European countries resulting in drought and consequent increased competition for water resources (FAO, 1996; Staykov, 1994; Szczerbowski, 1996; Varadi and Jeney, 1994).

Outlook

As in many other regions of the world, increasing demand for fishery products coupled with diminishing supplies from capture fisheries will continue to stimulate the further development and growth of the aquaculture sector within Europe. In 1996, export revenues from farmed salmonids in Norway reached US$1.1 thousand million, and it is generally expected that the production of Atlantic salmon alone in Norway will exceed 1 million mt by the year 2005 (Aalvik, 1997; Torrisen, 1995). In general, further expansion within the EU and northern European countries is likely to be constrained by limited site availability, competition for aquatic resources, stricter environmental controls, market development and cheaper imports from non-European countries. Apart from the northern European countries, where coastal site availability is not generally regarded as a limiting factor, considerable scope also exists for increased marine finfish and mollusc production in southern European countries such France, Spain, Italy, Malta and Greece through species diversification, the development of offshore cage technology, and improved product visibility and consumption through pro-active generic marketing.

In central and eastern European countries, freshwater aquaculture production is likely to increase in the future with increasing economic stability and the continued privatization of the sector, and with access to new potential markets in western Europe. Production increases will largely be achieved through the further intensification of existing traditional extensive and semi-intensive farming practices to more intensive farming methods and through the culture of higher-value species such as salmonids, marine finfish, eels, catfish, freshwater crustaceans, and molluscs.

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3.3 North America

Canada and the United States of America

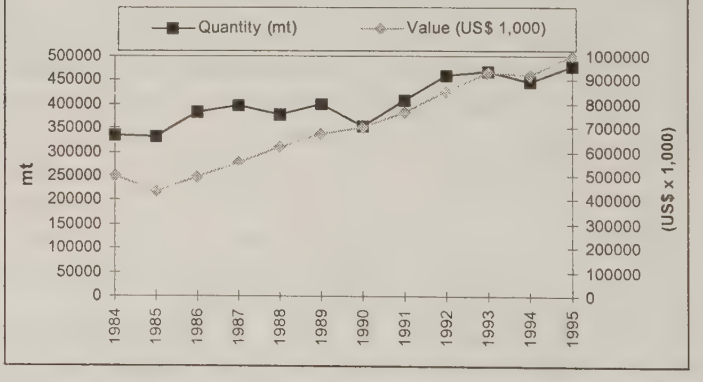
Bartley, D.

Production and production trends

Aquaculture is a steadily growing sector in the region; since 1984 production has increased by about 44%, from 334,000 mt to 480,000 mt at an APR of 3.3, while value of production has doubled, from US$498 million to US$999 million, at an APR of 6.5 (Figure 3.3.1). Total production in 1995 increased by 7.1% from 1994 and its value increased by 8.8%. (Global increases from 1994 to 1995 were 9.7% and 5.2% for quantity and value of production, respectively). Aquaculture accounted for 7.2% of total culture and capture fish production in the region in 1995, up only slightly from 5% in 1984.

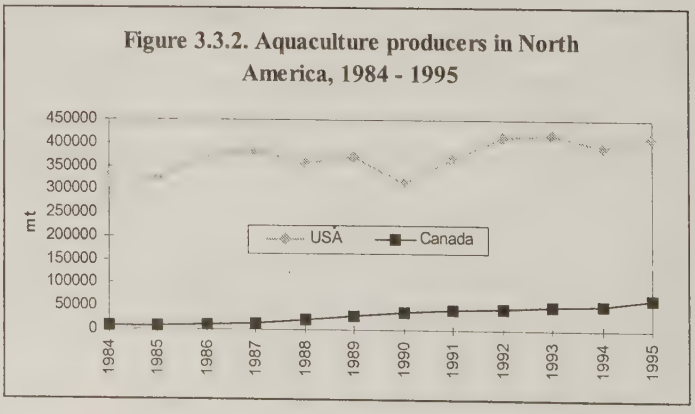
Per caput availability of fish and fishery products was 22.5 kg for Canada in 1993 and fishery products accounted for 5.8% of the total protein consumption. In the USA, per caput availability was 22.8 kg and fishery products accounted for 4.4% of total protein consumption.

Figure 3.3.1. Aquaculture production trends in North America, 1984 - 1995



The USA is the greater producer in the region (Figure 3.3.2), accounting for 86.2% of production and 73.0% of the value. Aquaculture production in the USA increased at an APR of 2.2 from 1984 to 1995, but in Canada it increased at an APR of 21.6, due to low baseline levels of production in the mid 1980s and steady increases in the 1990s.

Figure 3.3.2. Aquaculture producers in North America, 1984 - 1995



Production (1995) in the region is primarily from catfish (*Ictalurus punctatus*) from southeastern USA (203,000 mt; or 43% of total) (Figure 3.3.3), which has increased by 5.8% since 1984, but has declined slightly from a high of 208,000 mt in 1993 (Figure 3.3.4a). Production of the American cupped oyster (*Crassostrea virginica*) is also predominately from

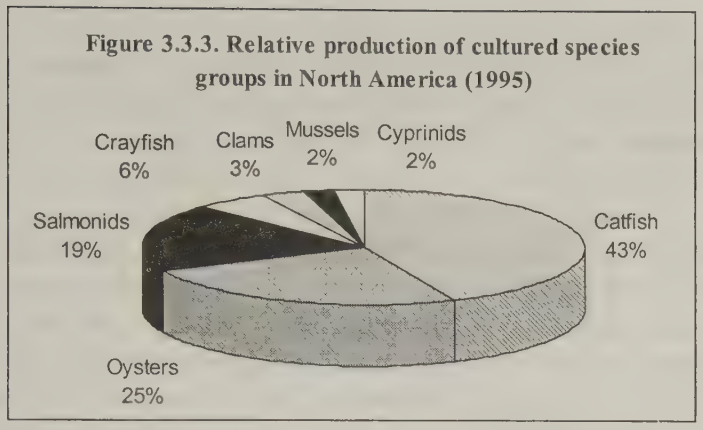


Figure 3.3.3. Relative production of cultured species groups in North America (1995)

the USA (except for 2,000 mt) and has declined since 1984 at an APR of about 3. Oysters, crayfish, and cyprinids have decreased at APRs of -1.7, -0.3 and -6.7, respectively (to 117,000 mt; 26,000 mt; and 10,000 mt in 1995), whereas salmonids, clams and mussels have increased at APRs of 11.9, 13.6, and 12.5, respectively (to 88,000mt ; 14,000 mt; and 10,000 mt in 1995) (Figure 3.3.4b). Crayfish (*Procambarus clarkii*) and the cyprinid *Notemigonus crysoleucas* which is used for bait, are exclusively cultured in the USA. Mussel culture has declined in the USA by an APR of 6.5 to 900 mt in 1995, but has increased in Canada at an APR of 24 to 9,000 mt.

In the USA, several species, such as tilapias, Atlantic salmon and striped bass, are showing substantial increases in production. Tilapia production has grown to 7,000 mt since 1987 at an APR of 130. Striped bass production, based on a hybrid between striped bass and white bass, has increased at an APR of 108 to 3,000 mt since 1985. Atlantic salmon has increased at an APR of 129 to 14,000 mt since 1986. The high rate of increase is often due to low initial production values in the 1980s, e.g. regular tilapia production started with 20 mt in 1988.

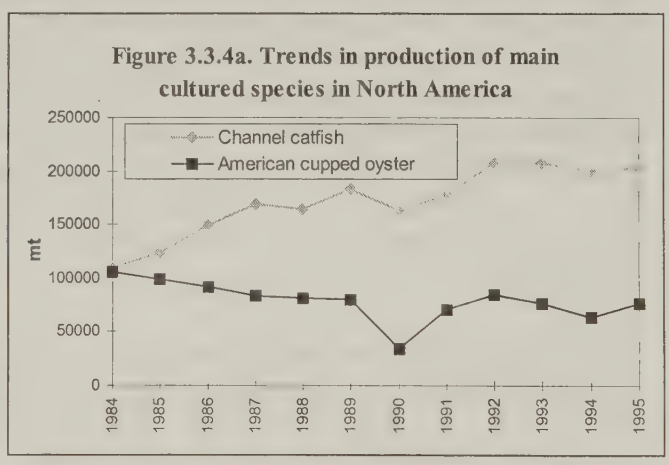


Figure 3.3.4a. Trends in production of main cultured species in North America

There are only nine taxa of aquatic animals cultured in Canada, all of which are salmonids or marine species. Atlantic salmon is the primary species farmed and production has increased by an APR of 57.8 since 1984 to 34,000 mt in 1995. Mussels, chinook salmon, Pacific cupped oysters and rainbow trout have all increased in production, by APRs of 24, 62, 5, and 11, respectively, while culture of coho salmon and American cupped oyster has declined from peak levels of production in the late 1980s. Overall growth rate of coho salmon from 1984 is still positive, however, at an APR of about 24 due to low initial production.

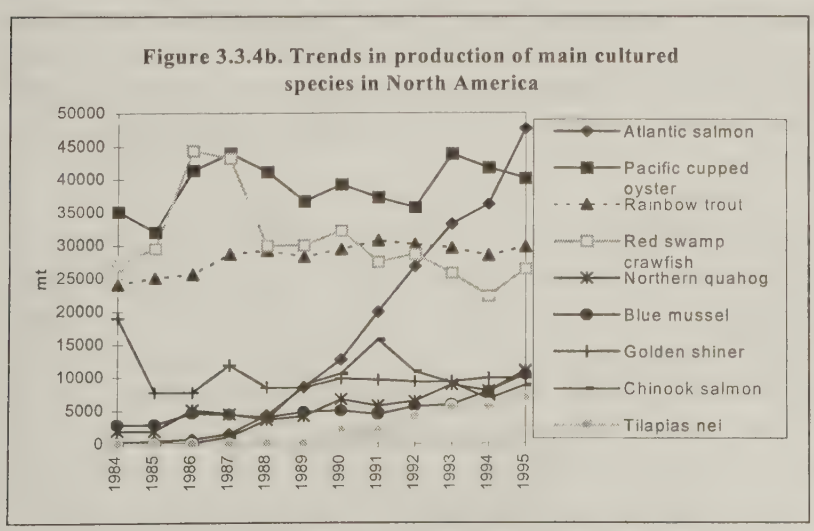


Figure 3.3.4b. Trends in production of main cultured species in North America

Production quantity from inland areas in the region increased with an APR of 3.8 from 186,000 mt in 1984 to 280,000 mt in 1995, and by an APR of 2.7 from 149,000 mt to 200,000 mt in coastal areas. Although value from inland aquaculture increased at a modest rate (APR 2.4) from

US$441.6 million to US$574.0 million, value from coastal aquaculture increased by an APR of 20.2 from US$56.2 million to US$425.3 million during 1984-1995. Coastal aquaculture accounts for 42% of the quantity of production and 43% of the value. As stated above, Canadian aquaculture is primarily from coastal areas.

Main issues

Aquaculture in North America involves diverse farming systems in diverse areas. However, the industry is currently facing challenges from environmental groups. The criticisms concern contamination of the environment by aquaculture systems through unwanted obstructions to coastal navigation; unsightly cages or pens; aquaculture effluents, such as excess food and chemotherapeutics; and the use of exotic species and fish that are either domesticated or genetically different from wild stocks. Governments, local and national, are responding to the issues raised by environmentalists and the industry must comply with environmental safeguards and environmental impact assessments. The industry in some areas may be forced to adopt closed culture systems in order to minimize harmful effluents, and to reduce the chance of fish escapes. At the same time, industry is requesting proof that certain practices harm the aquatic environment. For example, in Canada, growers may be required to raise only triploid salmon so that the chance of escaped hatchery fish breeding with wild stocks is reduced. The industry does not wish to be so constrained, because triploid fish often do not perform as well as diploids, and, as a result, the industry has asked for evidence that diploid salmon escaping from fish farms negatively affect wild populations (Stuart, 1996). The evidence at present is equivocal and this is a priority research topic. In addition, there is often antagonism at present between fish farmers and the fishers in the region. Fishers see farmed fish as an inferior product that floods the market and lowers prices; they also feel that escaped farmed fish would adversely affect wild fisheries. Marketing efforts appear to be underway to promote aquaculture as a green industry and to lessen the distinction between "farmed" and "wild" fish.

The regulatory mechanisms governing the industry appear to be complicated and involve numerous agencies with overlapping jurisdictions. In the USA there are the Coastal Zone Management Act, the Clean Water Act, the Endangered Species Act, the Lacey Act for transporting aquaculture products, and the Federal Food, Drug and Cosmetic Act, all of which impinge on aquaculture development; Departments of the Interior and Commerce and the US Department of Agriculture have partial oversight of the industry.

A strong US dollar will create a favourable atmosphere for increased import of fishery and aquaculture products. The USA industry will need to find means to remain competitive. One approach seems to be the establishment of growers' associations as has been done for catfish in the southeast and for tilapia. Recently a shrimp farming association was established to promote a strong domestic industry through improved marketing, government lobbying, and information dissemination and exchange.

Both countries in the region are highly developed and are applying modern biotechnology to aquaculture production. Catfish production owes much of its success to genetic improvement through conventional breeding programmes and to an active growers' association.. Other techniques to improve production are being used and tested, for example, triploid Pacific cupped oysters and transgenic common carp, catfish, Atlantic salmon and coho salmon. Initial results are that the transgenic fish show increased performance. However, there are environmental and human health concerns that must be addressed before there will be widespread consumer acceptance of these products of modern biotechnology (Bartley, 1997).

Aquaculture is also being used to support restocking programmes, either of commercially and recreationally important species, such as salmon, or of endangered species. The restocking efforts in the USA are extensive, releasing thousands of millions of fish (Bartley, 1996). The cost effectiveness of this practice and its effects on natural populations are controversial topics in need of further assessment.

Outlook

Aquaculture in the region can be expected to continue to grow slowly, although the industry will need to deal with environmental concerns and marketing of aquaculture products. Catfish production is expected to increase through additional acreage of ponds, in part due to favourable feed prices. Increased production from catfish and tilapia is expected to lower prices. However in salmon, production is level and no new sites have been approved for production (USDA, 1997). Complicated government oversight and regulatory process will also constrain the industry. Canadian aquaculture has been projected to grow to reach a quarter of the value of commercial fisheries by the year 2,000 (DFO, 1995). In the USA, species new to aquaculture, such as tilapia and abalone, are emerging, and may expand production. Production will also increase from the further domestication of aquatic species and the responsible application of genetic technologies to farmed aquatic organisms. Not all genetic technologies may be appropriate in the immediate future because of consumer or government resistance and unknown effects of some genetic modifications such as gene transfer. However, aquaculture developers in the region appear to be aware of these concerns and are helping to address public and government concerns through research, testing and compliance with current regulations.

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3.4 Latin America and the Caribbean

***Mexico; Central America**: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama*
***South America**: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Fr. Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela; **The Caribbean**: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Bermudas, Cayman Is., Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Jamaica, Martinique, Montserrat, Netherlands Antilles, Puerto Rico, Saint Lucia, St. Kitts and Nevis, Trinidad and Tobago, Turks and Caicos Is., British Virgin Islands, US Virgin Islands*

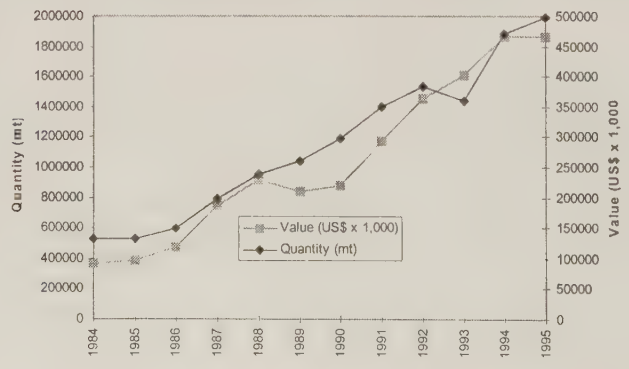
Martinez, M. and M. Pedini

Production and production trends

Aquaculture in this region continued growing steadily during 1984-95, with an APR of 12.8 (Figure 3.4.1). Total production in 1995 was 499,000 mt with a value of US$1.87 thousand million, representing 1.8% and 4.4% of world production by volume and value, respectively. In the same year, aquaculture contributed 2.3% in volume to the total production in this region from capture and culture. Production from seven countries accounted for 92% in volume of the total aquaculture production in the region in 1995: Chile (41.4%) and Ecuador (18.3%) were by far the main producers, followed by Mexico (13.8%), Colombia (7.3%), Brazil (6.1%), Cuba (4.2%) and Costa Rica (1.4%) (Figure 3.4.2).

Three sub-regions can be clearly differentiated: South America, Central America (including Mexico) and the Caribbean. All the eight countries from Central America (including Mexico), the 14 countries from South America, and 13 out of 23 in the Caribbean sub-region have reported 1995 aquaculture data to FAO.

Figure 3.4.1. Aquaculture trends in Latin America and the Caribbean, 1984-1995

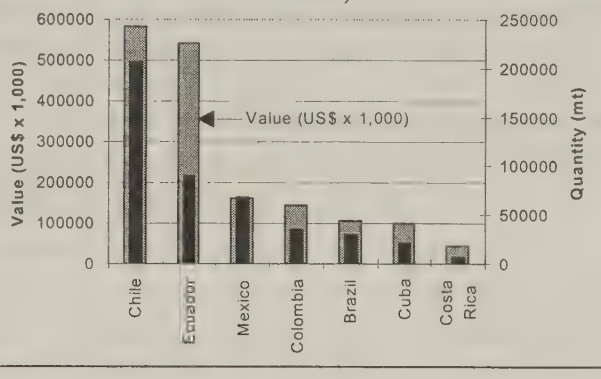


In 1995, production in volume was 378,000 mt (75.8%) in South America, 94,000 mt (18.9%) in Central America, and 26,000 mt (5.3%) in the Caribbean. South America had a rather high APR of 21.8, typical of an emerging activity, during 1984-1988, followed by a lower APR of 15.1 over the next six years, 1990-1995 (but still above the world APR of 12.1 for the same period), as to be expected from an already consolidated sector. Central America had a low APR of 7.1 during

the first six years and an even lower APR of 2.2 during the second period, which means that aquaculture has not yet taken off in that sub-region. The Caribbean sub-region shows a similar pattern, with an APR of 6.7 for the 1984-1989 period and an even lower APR , 0.2, for 1990-1995.

A specific characteristic of aquaculture in Latin America is that it is mainly export oriented, with shrimp and salmonids as the main export products. Shrimp culture in Ecuador, the main producing country, showed rapid growth during 1984-1889 (APR 16.5) followed by moderate growth during 1990-1995 (APR 3.0).

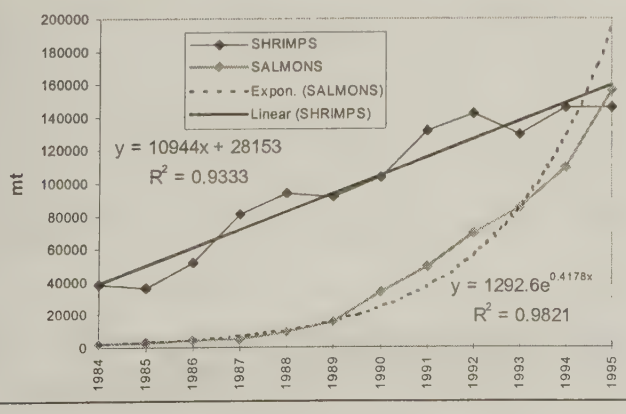
Fig. 3.4.2. The seven main aquaculture-producing countries in Latin America and the Caribbean, 1995



Culture of salmonids and shrimp, which are exported to the USA, Japan and Europe, accounted for 82.1% of the total value of regional aquaculture production in 1995. Salmonid production in Chile accounted for 28.4% (141,000 mt) by volume and 30.5% by value of total aquaculture production in the region; shrimp production in Ecuador represented 18.2% (90,000 mt) of total regional aquaculture production in volume and 51.5% of total value. The growth in aquaculture production of shrimp during 1984-1995 was linear while that of salmon was exponential (Figure 3.4.3).

Salmonid culture has developed almost exclusively in Chile with a growth rate superior to any other culture activity in the region (APR 1984-1989, 88.2; APR 1990-1995, 37.7). Production in 1995 (141,000 mt) represented 15.0% of world salmonid aquaculture production. The proportions by volume of production of the three cultured species in 1995 were: rainbow trout (*Oncorhynchus mykiss)*, 37%; Atlantic salmon (*Salmo salar),* 35%; and coho salmon (*O. kisutch)*, 28%. Salmonid cage farms are concentrated in the southern coast of the country where the lakes for smolt production are also located. The industry has benefited from numerous protected coastal areas, cheap fishmeal derived from the rich anchoveta fishery, and alternate harvesting seasons with respect to European producers. Significant foreign investment has been attracted by these conditions plus cheap labour and a sound political will to develop the sector.

Fig. 3.4.3. Trends in production of the two main cultured species groups in Latin America and the Caribbean, 1995



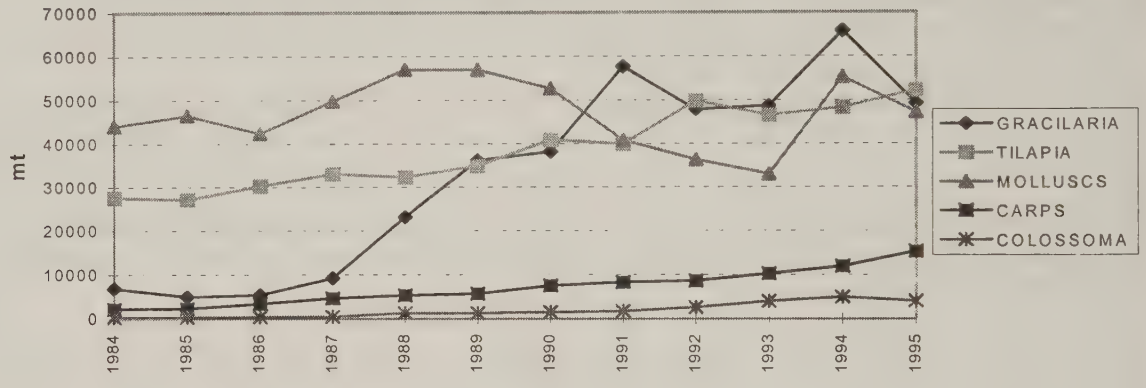
Trout culture, a traditionally stagnant activity in most of the region, has had an impressive growth in Chile from 20 mt in 1988 to 40,000 mt. in 1995. Other countries seem to be following this trend: Colombia with 9,000 mt in 1995, Mexico with 1,500 mt, and Argentina with 1,400 mt.

Shrimp production grew at an APR of 12.8 during 1984-1995. Production in 1995 (146,000 mt) represented 15.6% of world shrimp

aquaculture production. The proportions by volume in 1995 of the main cultured species were: white shrimp (*Penaeus vannamei*), 72.0%; and blue shrimp (*P. stylirostris*), 6.8%. In 1995, 11 countries produced more than 1,000 mt of shrimp: Ecuador (62.4%), Mexico (11.0%), Colombia (5.6%), Panama (3.6%), Honduras (3.5%), Peru (3.2%), Guatemala (2.0%), Costa Rica (1.8)%, Nicaragua (1.7%), Brazil (1.4%), and Belize (1.2%).

Shrimp culture in Ecuador started in 1979. Colombia, Brazil, Honduras, Panama and Peru started at the beginning of the 1980s, followed by Mexico in 1985, Costa Rica 1987, Venezuela 1988, and Belize in 1989. Shrimp culture in Latin America has been from the beginning and with minor exceptions an industrial-scale activity.

Fig. 3.4.4. Trends in production of main cultured groups in Latin America and the Caribbean, excluding shrimps and salmons, 1995



Production trends of the other five main commodities for the period under review are shown in Figure 3.4.4. *Gracilaria* is mostly produced in Chile (49,000 mt in 1995). In 1987, growth of this activity began to accelerate. The growth curve started flattening again in 1992, and since then production has increased very little (APR 1984-1995, 19.7; APR 1990-1995, 5.3).

Oysters (*Crassostrea virginica*) account for about 65% of mollusc production in the region. There was a decline during 1989-1993, and although production seems to be recovering, it has not yet reached previous levels (APR 1984-1995, 14.9).

Freshwater fish culture accounted for 19.8% by volume of total aquaculture production in the region in 1995. Culture of red tilapia has experienced the highest growth rate due to the high prices it fetches in export markets. In spite of the enormous existing potential, very few native freshwater fish species are being cultured in the region. Tilapia culture shows a steady increase which seems bound to continue (APR 1984-1995, 12.7). The main producing countries are Colombia, Mexico, Cuba, Costa Rica and Jamaica. This is the main species group cultured at the rural small-scale level. Some important cases of intensive culture are those in Jamaica (2,800 mt in 1995) and Costa Rica (3,800 mt in 1995). The proportions by volume in 1995 of the main cultured species were: *Oreochromis* spp., 43%; *O. niloticus*, 37%, and *O. aureus,* 19.7%.

Production of carps, the main species being *Hypophthalmichthys molitrix* (65%) and *Cyprinus carpio* and of colossoma (*Colossoma brachypomum* (79%) is the main species of

the group) has shown a very moderate growth although they have been present in regional production statistics for more than 15 years. The causes of stagnation in the culture of these promising species are still not clear.

Commercial-scale marine fish culture began in Chile in 1991, and in 1995 turbot (*Psetta maxima*) culture was at the pilot stage. Culture of other marine fish, such as red-drum (*Sciaenops ocellatus*), is entering the pilot phase (in Martinique) but has been commercialized only at the sub-regional level. Other species, still in the experimental phase of culture, include: pompano (*Trachinotus* spp.), snook (*Centropomus* spp.), snapper (*Lutjanus* spp.), mullets *(Mugilidae*), and carangids (*Seriola* spp.). Development of the technology to culture snook is well advanced and this activity is expected to enter the pilot stage very soon. The main problems encountered in marine aquaculture are the scarcity of technologies for local species, the fact that most of the experimental species are carnivorous, and competition with capture fisheries, the products from which are very often low priced.

Main issues

Although there are considerable areas of physical and resource potential, only industrial-scale, export-oriented aquaculture has had significant growth in the region; and this type of activity still has a moderate potential for growth. Other kinds of aquaculture, such as of molluscs, aquatic plants and freshwater fish, as well as rural aquaculture and pond-based fisheries in reservoirs, have grown at a rate slower than expected, considering their potential and the economic needs of the countries resulting from recent trade and finance conditions; most of these forms of aquaculture are oriented toward domestic markets. The difficulties encountered in promoting aquaculture for domestic markets in the region are not linked to existing physical resources, but mainly to institutional factors, as well as to research and entrepreneurial capacity. With very few exceptions, aquaculture in the region is not properly integrated into government structure and policy frameworks. In addition, structural adjustment policies have reduced the governments' capacity to promote and develop aquaculture oriented towards the production of cheap products for the poor. Competition with inland fisheries production is sometimes a serious hindering factor for aquaculture development.

Trends towards shrimp culture intensification have decreased in recent years due to disease problems. During 1992-1995, Ecuadorian shrimp culture was affected by increased incidence of disease (mostly Taura Syndrome virus), which caused drastic production drops. Measures taken to avoid this problem have included stocking at lower densities, less feeding and less water pumping. The epidemic initially promoted diversification, because some farms that were closed by the virus started culturing *Cherax* spp. and finfishes such as tilapia and redfish, as well as polyculture of shrimp and tilapia. This tendency slowed down when the Taura Syndrome virus impact decreased.

Latin America has about 11 million ha of water surface in reservoirs. It is estimated that present production through fisheries and pond-based fisheries in these water bodies represents only a small percentage (about 12%) of its potential. The main constraints for this development are managerial and very much linked to institutional problems.

In general, freshwater culture in the region is making little use of alternative ways to increase production such as through fertilization, polyculture and integration with other farming systems. The prevailing technology uses expensive and sophisticated high energy-consuming methods: high stocking densities, exclusive use of commercial feed, and methods to increase the carrying capacity of the ponds, such as aeration and strong water exchange. Apart from

any social concern, a monoculture technology based on the stocking of fingerlings that are fed with expensive commercial feed and harvested for export markets, does not seem to be an economically sustainable activity for small-scale rural farms.

In summary, aquaculture development in the region is hindered by problems which can be grouped in the following categories:

- *Environmental.* Problems mostly related to industrial-scale aquaculture are beginning to arise. Mangrove cutting in Ecuador, and conflicts with capture fishery activities in several countries, mainly due to alleged destruction of larval resources, are some of the consequences of culture intensification and wrong farm site location.
- *Climatic.* Events such as El Niño, which has had impact on the shrimp culture industry on the Pacific coast of the region through floods and undesirable changes of temperature, and hurricanes in the Caribbean area, are important concerns for aquaculture farms.
  Biological/technical. Diseases are affecting not only shrimp culture (viral) but also oyster culture (parasites). In many cases, the treatment is totally unknown. The reproductive cycles of several aquaculture species are also not fully understood. Seed supply is a serious limiting factor in many areas, affecting industrial, semi-commercial and rural aquaculture.
- *Institutional and legal framework.* There has been delayed reaction to developments in the aquaculture sector.
- *Social.* These problems are related to land tenure, conflicts on the use of certain resources, access to aquaculture products by the poor, and personnel (processing workers, larvae collectors, etc.).
- *Economic.* Instability, frequent currency changes, high inflation rates, high commodity prices and competition with capture fisheries are some of the main economic problems.

Outlook

The Latin America and Caribbean region has been characterized by macro-economic changes in the last two decades. Even in recent years, fluctuations in currencies and inflation rates in some of the major countries have created difficulties for investment in aquaculture, still a relatively new industry in the region. Mid- and long-term projections for aquaculture production are therefore particularly speculative, and this paper will only attempt to provide an outlook for the short-term scenario, 1995-2000. The more recent APRs for countries and species provide some guidance on how aquaculture production may evolve in the region.

Aquaculture growth in the Caribbean has stagnated in the last five years due to the Cuban crisis. This country strongly influences projections for the sub-region as it contributed over 78% of Caribbean production in 1995. The rest of the countries seem to have reached a situation of slow growth. The Cuban government is committed to invest in aquaculture development for food security reasons, and is investing in new stations. Growth rate of the sector may be expected to increase markedly, although the targets established in 1996 for the year 2000 appear to be too optimistic. A production of 60,000 mt per year by 2000 would be a very good result which would bring the annual total for the Caribbean to about 70,000-75,000 mt. This growth is likely to be due to culture of tilapias in more intensive systems and to the farming of Chinese carps. An expansion of crustacean culture in the Caribbean, mainly for export, will also see Cuba as the main producer.

Central America had a low APR in 1990-1995 due to the poor performance of the sector in Mexico, which contributed 72% of the production of this sub-region. The outlook for Central America is a relatively fast growth of shrimp culture on the Pacific coast due to the combined efforts of Mexico, Guatemala, Honduras, Nicaragua and Panama. Shrimp culture has taken

off in these countries since 1990 with APRs ranging from 9 to 104 in 1990-1995, and this growth is expected to continue, disease epidemics permitting. It is likely that future growth may accelerate with a more important contribution of shrimp culture to the total production than at present. Mexico has potential for areas to be developed, already-established marketing channels for export, and investment programmes that have been recently promoted by the Government with assistance of the World Bank. All this suggests favourable growth prospects, in spite of the complex institutional situation which may be an impediment to rapid growth. A contribution of about 70,000 mt of cultured shrimp by year 2000 for Central America is not unreasonable (an APR of 15 for 1995-2000), and a similar output could be expected for other commodities (APR 4) bringing the total to 140,000 mt per year by 2000.

In South America, the major prospects for expansion of production are with salmonids, shrimp, tilapia and *Gracilaria*. Salmonid culture is concentrated in Chile, which produces 90% of the sub-region's total salmonid production, and has recorded APRs ranging from 27 to about 80 for the three major species. Prospects for APRs in the order of 20 in the short term may even be conservative considering the advantages of the country for salmonid production, and the fact that it is already an established industry. Projected overall annual salmonid production of the sub-region by the year 2000 would be about 350,000 mt. Shrimp production is mainly in Ecuador (84% of the total output), but the growth rate in 1990-1995 slowed down to an APR of about 3 due to the saturation of areas under culture and the incidence of diseases. Future prospects may not be very different from present rates and will be based on sustainable extensive/semi-intensive farming practices, and measures to control diseases. However, other countries of the sub-region such as Venezuela and Brazil may experience much faster growth of shrimp culture due to the availability of suitable areas and the stagnation of supply at the world level, which could encourage investment. An annual total of about 140,000 mt could be expected for year 2000 at an APR of 5. Tilapia culture is one of the fastest growing sub-sectors, pushed by the availability of export markets and the introduction of intensive production packages. Production is concentrated in Colombia and Venezuela and this situation is expected to remain stable up to year 2000. A conservative APR for these two countries of around 30 would mean an annual production level of about 67,000 mt by year 2000. *Gracilaria* culture is also concentrated in Chile and is expected to stabilize at about 65,000 mt annually by 2000, although the extensive nature of the production and the climatic variation in the sub-region may produce considerable variations in output from year to year.

Overall, the contribution of the major cultured groups is expected to increase the supply of aquaculture products, mainly oriented to export, from the 330,000 mt (87% of the total production) in 1995 to about 622,000 mt by 2000. Adding the rest of the species farmed, total annual regional aquaculture production could be expected to be about 690,000 mt by year 2000.

3.5 Former USSR Area

Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakstan, Kyrgyzstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan

Barg, U.

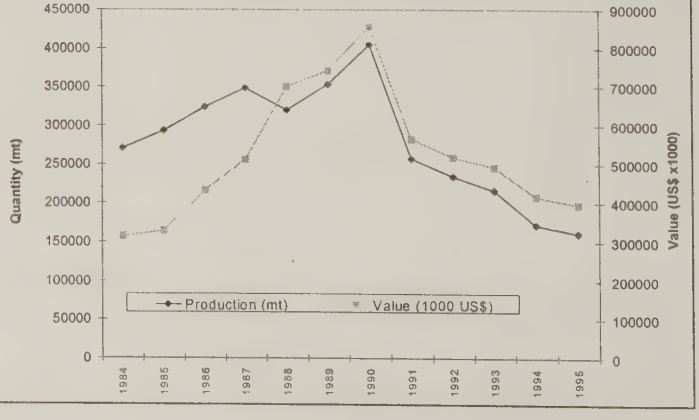
Production and production trends

Total aquaculture production in 1995 in the countries of the former USSR area amounted to 161,000 mt, valued at US$395 million. The contribution of this region to world total aquaculture production and value in 1995 was 0.6% and 0.9%, respectively. Total production in the region has decreased since 1984, when total aquaculture production in the former USSR was 271,000 mt, valued at US$313.7 million. The decrease in production (APR 1984-1995, -4.6), and the increase of its value (APR 1984-1995, 2.1), however, were not continuous throughout this period (Figure 3.5.1). Production and value showed significant increases from 1984 to 1990 (APR 6.9 for production, and 18.1 for value), when total aquaculture production peaked at 404,000 mt, valued at US$856.1 million. In 1990, this region contributed 2.6% in terms of production and 3.2% in terms of value to world aquaculture production.

There was a drastic decrease in total production and value from 1990 to 1991 of 36.6% and 34.2%, respectively, when production and value dropped to 256,000 mt and US$563.6 million, respectively. Since 1991, total production and value of aquaculture have continued to decrease, although at slower rates, with APRs (1991-1995) of about -11.0 for production and -8.5 for value. Total production in 1994 was 171,000 mt, valued at US$417.3 million The decrease in production for the 1994-1995 period (6.1% for production, and 5.3% for value) may indicate that the rate of decline in aquaculture production, and its value, is slowing.

The four main producing countries in the region are the Russian Federation, Ukraine, Belarus and Uzbekistan where aquaculture production contributed 42.6%, 28.7%, 8.8% and 6.3%, respectively, to the total 1995 aquaculture output of the region. The decrease in total national production during the period 1988-1995 was most significant in the Russian Federation, Ukraine and Uzbekistan, with APRs of -10.9, -9.9 and -9.5, respectively. Aquaculture production in Belarus

Figure 3.5.1. Aquaculture production trends in the former USSR area, 1984 - 1995



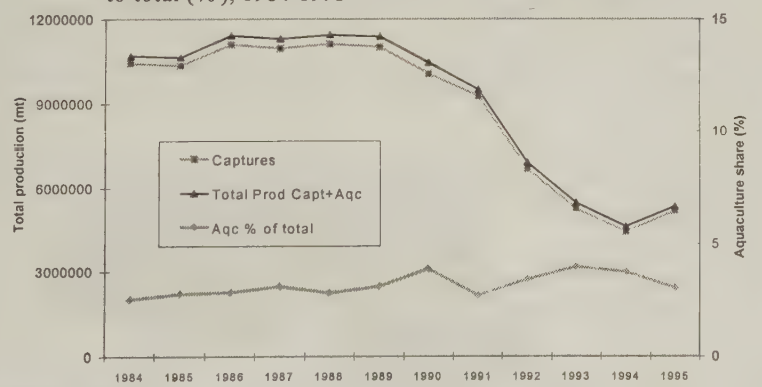
decreased at a much lower rate (APR -1.8). Recent production statistics may indicate that production in Ukraine and Belarus is increasing (5.7% and 3.7% increase in 1994-1995, respectively), whereas in the Russian Federation and Uzbekistan there were decreases of 12.0% and 30.0%, respectively in 1994-1995, indicating that total national aquaculture output in these countries has continued to decline.

The eleven "minor" producing countries in this region, taken as a group, produced 13.6% of the total regional output in 1995. Collectively, these countries also experienced a decrease in aquaculture production during 1988-1995 (APR -5.5), although recently there appear to be slight increases (1.5% in 1994-1995) in production in this group. However, the individual 1994-1995 growth for these countries showed different percentage increases: Armenia 3.4; Azerbaijan 7.0; Estonia -24.5; Georgia 9.3; Kazakstan 3.4; Kyrgyzstan 9.8; Latvia -6.2; Lithuania -8.5; Moldova Republic 2.0; Tajikistan 2.5; and Turkmenistan -8.5.

Throughout 1984-1995, aquaculture production in this region never contributed more than 4% to total fish production (Figure 3.5.2). Total fish production has declined significantly from peak levels of 11.4 million mt in 1986 and 1988 down to 4.6 million mt in 1994. Highest relative contributions by aquaculture were reached in 1990 and 1993, with 3.9% of 10.5 million mt, and 34.0% of 5.5 million mt, respectively. The 1995 share of aquaculture to total fish production (5.3 million mt in 1995) was 3.0%, down from 3.7% in 1994. This was mainly due to an increase in capture fisheries landings of 751,000 mt in 1995.

Most aquaculture production in this region is derived from freshwater aquaculture. In 1995, inland aquaculture produced 152,000 mt, valued at US$376 million, while coastal aquaculture contributed only 5.6% of total aquaculture production, or 4.8 % of its total value. The relative contribution of inland aquaculture to total production of freshwater fish (including both inland aquaculture and inland capture fishery landings) in 1995 was 31%, after reaching 40% in 1990 and 37% in 1993 (Figure 3.5.3). Aquaculture production is based primarily on the use of freshwater finfish species, with other major species groups still playing a minor role (Figure 3.5.4).

Figure 3.5.2. Total fish production (capture fisheries plus aquaculture, mt), and relative contribution by aquaculture to total (%), 1984-1995

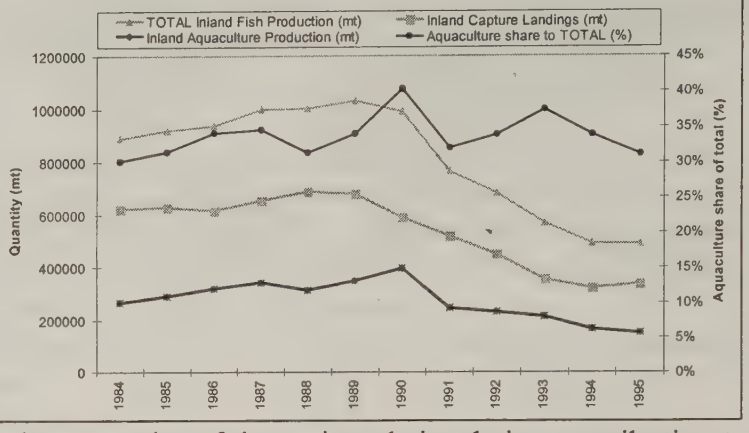


The two dominant species produced in the region are common carp and silver carp. The production of these two species contributed 81.2% of the total aquaculture output in 1995. Common carp production decreased during 1984-1995 at an APR of -6.5; in 1994-1995, production dropped by 14.3%. Negative production trends in silver carp were less pronounced, with an APR of -4.4 over 1984-1995 and a 2.3% drop in 1994-1995. Aquaculture of brown seaweeds, freshwater fishes *nei*[1], cyprinids *nei*, white-fishes *nei* and bighead carp together generated 13.8% of the 1995 output (Table 3.5.1). The remaining 5% of production was derived from aquaculture of channel catfish, sea trout, Mediterranean mussel, freshwater bream, grass carp (= white amur), sturgeons *nei*, sea mussels *nei*, mullets *nei*, pike-perch,

[1] not elsewhere included

goldfish, Yesso scallop, flatfishes *nei*, freshwater crustaceans *nei*, trouts *nei*, snakeheads (= murruls), asps, wels (= Som catfish) and buffalofishes.

Figure 3.5.3. Total inland fish production and contributions by capture fisheries and aquaculture, 1984-1995

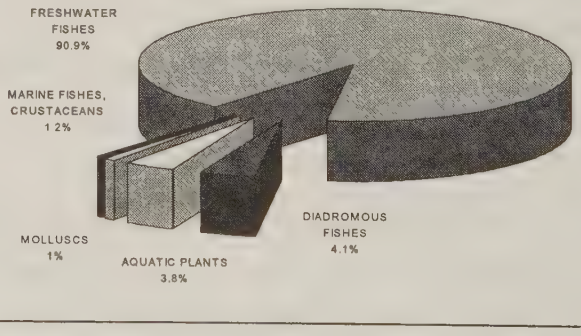


The Russian Federation was and continues to be the main producer of common carp and silver carp in the region (Table 3.1.51), followed by Ukraine, Belarus and Uzbekistan. Even though production of these two species is considerably lower in all other countries of the region, their relative contribution to total aquaculture production in these countries is very significant (Figure 3.5.5). The exception is Estonia, where production of rainbow trout accounted for 88.3% of total national output, and for 27.7% of total production in the region, ranking third as major rainbow trout producer, after Armenia and Ukraine which in 1995 contributed 35.8% and 34.8%, respectively, to the total regional production of 1005 mt. Channel catfish is mainly produced in Ukraine which contributed 1,300 mt or 92.9% of total regional production. The Russian Federation accounted for 1,100 mt (or 100%) of sea trout produced in the region. Total regional production of Mediterranean mussel in 1995 was 1,075 mt, of which 53.5% were produced in the Russian Federation and 46.5% in the Ukraine.

Main issues and outlook for increased food production

There has been a very noticeable drop in recorded production in the region, in both aquaculture and the wider agricultural sector, since the change of political system and the break-up of the state structure (Muir, 1995). Note that since 1988, statistical data on aquaculture in the former USSR area, which were grouped earlier under the USSR, have been separated and reported by FAO under the individual countries of the former USSR. Because of this, there may well be problems in recording and reporting appropriate production data from aquaculture and inland capture fisheries, which makes it difficult to define the actual patterns of production and availability of aquaculture products for domestic food supply.

Figure 3.5.4. Relative production of major species groups cultured in the former USSR area (total production 1995: 161,149 mt)



The economic and political changes taking place in the region, due to the transition from centrally-planned to market economies, have had a tremendous impact on all sectors in the countries, including the fishery sector (FAO Fisheries Department Task Force, 1995; see also FAO, 1994; 1995; 1996a). According to FAO (FAO, 1996a), the decline of agricultural output, which affected the region since the beginning of the transition, continued in 1994 and 1995. The sector has been hit by the demise of former support policies, demand decline linked

to real income reduction, the difficulties of the farm-restructuring and enterprise-privatization processes, and the disruption of trade among the republics of the former USSR (FAO, 1996a). In 1995, crop and livestock production continued to decline in some of the major republics of the former USSR, such as the Russian Federation, Ukraine and Kazakstan (FAO, 1996a). In Armenia, the food supply situation continues to improve as a result of increased trade and donor assistance. However, a section of the population seriously lacks resources to purchase food and, together with refugees and internally displaced people, continues to need assistance.

Table 3.5.1. Production of main species and main producing countries in the former USSR region in 1995 (total aquaculture production in 1995: 161, 149 mt).

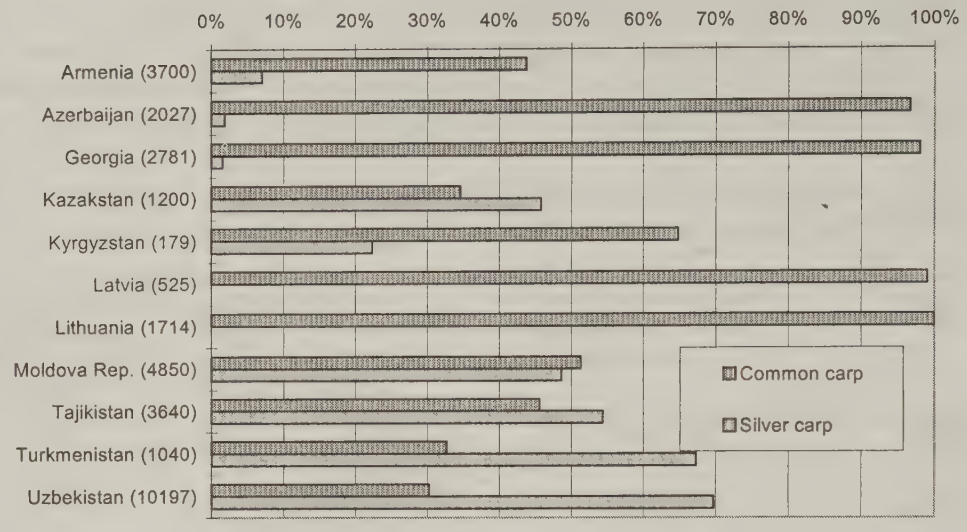
Species	Production (mt) and share (%) of total aquaculture production	Top producing countries (% of total production of species within region)	Species share (%) of total aquaculture production within country
Common carp	**94,276 (58.5)**	**1. Russian Fed. (35.4)**	48.7
		2. Ukraine (31.8)	64.9
		3. Belarus (15.1)	99.9
		4. Uzbekistan (3.3)	30.2
		5. Georgia (2.9)	98.1
Silver carp	**36,594 (22.7)**	**1. Russian Fed. (45.1)**	24.1
		2. Uzbekistan (19.4)	69.7
		3. Ukraine (19.1)	15.2
		4. Moldova Rep. (6.4)	48.7
		5. Tajikistan (5.4)	54.4
Brown seaweeds	**6,560 (4.1)**	**Russian Fed. (100)**	9.6
Freshwater fishes *nei*	**5,070 (3.1)**	**1. Ukraine (69)**	7.6
		2. Russian Fed. (31)	2.3
Cyprinids *nei*	**4,170 (2.6)**	**Russian Fed. (100)**	6.1
Whitefishes *nei*	**3,463 (2.1)**	**1. Russian Fed. (57.8)**	2.9
		2. Armenia (42.2)	39.5
Bighead carp	**3,000 (1.9)**	**Ukraine (100)**	6.5

In Azerbaijan and Georgia, although some recovery in food production is anticipated in 1996, the food supply situation remains difficult because of economic problems and reduced imports. In Tajikistan, the food supply situation is extremely serious, with those populations most at risk being threatened by starvation in the absence of international assistance (FAO, 1996a).

Significantly, these economic and political changes have entailed a drastic drop not only in total fish production but also in fish consumption or availability of fish for human consumption. Fish as a human food commodity in this region is relatively important, providing 10.2% of total dietary protein supply, as estimated for 1990-1992 in FAO's Sixth World Food Survey (FAO, 1996b).

Available data on per caput supply of fish and fishery products show that *apparent* consumption of fish in the Russian Federation has decreased from 22.7 kg in 1991 to 15.5 kg

Figure 3.5.5. Common carp and silver carp production relative to total aquaculture production (mt) in 11 former USSR countries (1995)



in 1993, in addition to a significant decline in supply of animal (i.e. non-fish) protein from 57.3 g per caput per day in 1991 to 46.6 g per caput per day in 1993, resulting in the reduction of the ratio of fish/animal protein from 15.8 % in 1991 to 11.5% in 1993 (Laureti, 1996). It is noteworthy that Zaitsev (1996) reports a decline in average annual consumption of fish and fishery products in the Russian Federation from 15.8 kg (edible weight) per caput in 1991 to 9.5 kg per caput in 1993, and a decline in consumption of meat and meat products from 69 to 55 kg per caput for the same period. The FAO Fisheries Department Task Force (1995) quotes Russian data reported by Chuksin (1994), which indicate a drop in *apparent* consumption of fish and fishery products from 29 to 9 kg per caput for 1989 and 1993, respectively. However, production shortfalls have also resulted in rising prices and steadily increasing imports of fish and fishery products, with the Russian Federation in 1995 leading the way in Eastern European countries, by importing a total of 481,000 mt, mainly fresh, chilled, frozen or canned fish, valued at US$346 million (Anon., 1997). The significant increase in imports of frozen pelagics, namely mackerel and herring, by Eastern European countries, has created opportunities for western exporters (Lem, 1997).

Unfortunately, there is little information on trends in supply of fish for human consumption in the seven LIFDCs[2] of the region, namely Armenia, Azerbaijan, Georgia, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. Table 3.5.2 provides the most recent indicative estimates for per caput supply of fish and fishery products, animal proteins, and ratio of fish to animal proteins consumed in these countries. Even though the estimates for fish supply do not include possible trade of fish and fishery products to and from these countries (trade statistics are not available), it may be seen that fish supply from domestic sources has generally declined in this country grouping, with sharp reductions evident for Georgia and Turkmenistan. All countries suffered significant reductions in supply of animal protein from 1991 to 1993 (Laureti, 1996).

In the context of the recent evaluation of aquaculture development perspectives for food security, the countries of the former USSR (in addition to Africa, Asia and South America) have been recognized as primary targets for attention for food supply and food security (Muir,

[2] Low-income food deficit countries

1995). Perspectives for aquaculture development and food security in the region were summarized by Muir (1995), as follows:

Region	Food security significance	Positive development features	Potential constraints	Overall prospects with respect to food security
Former USSR	Depends on political outcomes, may be serious	Natural resources, local skills, response to new techniques	Pollution, management structures, financial and market development	Uncertain; needs political, economic stability, better resource management

In addition to the consequences of the major economic and political changes, aquaculture and inland capture fisheries in many cases continue to face problems resulting from environmental impacts on water quality and quantity affecting living aquatic resources (FAO Fisheries Department, 1996a; 1996b). The environmental degradation of inland waters through industrial, urban and agrochemical pollution, and damming of major rivers has had significant local impacts on fish stocks. As a result of the large-scale uptake of water for irrigation, the original fish fauna of Central Asia have been significantly modified (Kamilov and Urchinov, 1995; Pavlovskaya, 1995; Urchinov, 1995); similar problems of damming and water withdrawal affecting capture fisheries and culture-based fisheries are being reported for Kazakstan, Russian Federation, Ukraine, Azerbaijan and Latvia (Berka, 1989; Petr, 1995; Petr and Mitrofanov, 1995; FAO Fisheries Department, 1996a; Afanasjeva, 1997). Major concerns have also been raised regarding the gradual desiccation of the Aral Sea, affecting species migrating in rivers of the Aral basin (Berka, 1989; FAO Fisheries Department, 1996a).

Table 3.5.2. Per caput supply of fish and fishery products, animal proteins and ratio of fish to animal proteins in the seven regional LIFDCs in 1991 and 1993 (Source: Laureti, 1996)

Country	Per caput supply (kg/year) of fish and fishery products		Availability of animal proteins (g/caput/day)		Fish/animal proteins (%)	
	1991	1993	1991	1993	1991	1993
Armenia	1.3	1.2	52.4	19.4	0.8	1.9
Azerbaijan	5.5	4.9	37.8	27.8	4.4	5.3
Georgia	11.2	6.9	31.5	20.5	12.1	11.2
Kyrgyzstan	0.3	0.1	42.4	35.0	0.2	0.1
Tajikistan	0.7	0.7	18.9	12.8	1.2	1.5
Turkmenistan	11.5	7.8	36.2	34.0	9.5	7.5
Uzbekistan	1.3	1.1	31.7	24.4	1.2	1.4

Among the many problems aquaculture producers are facing due to the impact of recent economic and political changes, is the shortage of feedstuffs, fertilizers and fish therapeutants, as experienced by Armenian fish farmers (GLOBEFISH/FAO, 1997). In the Russian Federation, import duties caused a reduction in the supply of proper feeds, resulting in plans by salmon farmers to set up local fish feed factories (GLOBEFISH/FAO, 1997). Similarly, the productivity of Lithuanian carp farms has declined in recent years due mainly to increasing use of corn in carp feeds, which is due in turn to high costs of manufactured feeds imported from Ukraine (Jakstiene, 1997). It may appear that aquaculture producers have also suffered from the generally sharp deterioration of the terms of trade between agricultural producers and input suppliers, which has caused dramatic decreases in usage, sales and production of inputs (see FAO, 1996a). Other major difficulties faced by aquaculture producers may

include: (i) uncertain legal status of farm ownership due to different privatization and decollectivization processes for farms of varying size; (ii) the need to re-establish new distribution and marketing channels, for both lower- and higher-priced aquaculture products within the countries, between the countries of the region, and to more industrialized countries or regions such as Japan, Europe and North America; (iii) severe lack of capital for required restructuring and maintenance of existing farms, and for investment in new aquaculture development opportunities; and (iv) the urgent need for institutional support and technical advice on viable and sustainable joint ventures with foreign investors.

The economic and political changes have also had significant effects on inland capture fisheries, which were or continue to be subsidized through stocking and fertilization programmes (FAO Fisheries Department, 1996b). It should be remembered that official data for inland capture fisheries may in many cases be underestimated (FAO Fisheries Department, 1997). Production from subsistence and recreational fisheries is seldom accurately reflected in the statistics, and it is likely that production from these sectors plays a rather important role for food supply in the countries undergoing economic and political transition (FAO Fisheries Department, 1997). However, capture fisheries in many inland waters of the region, including, in particular, reservoirs and lakes, continue to depend heavily on stocking of fry and fingerlings produced in hatcheries, lake farms and artificial spawning grounds, or by other types of enhancement measures (Berka, 1989; Voronin and Gavrilov, 1990; Karpova et al., 1996).

Improved stocking and fisheries management measures have considerable potential for significant increases in fish production from reservoirs and lakes in some countries of the region (Coates, 1995). It is conservatively estimated that fisheries production from reservoirs in western countries of the region can be increased between four and six fold by improved stocking; inland fish production in the Russian Federation could realistically be doubled in the next decade (Coates, 1995). It is expected that recreational fisheries, often contributing significantly to household food supply, will gain increasing importance in eastern European countries of the region (EIFAC, 1996), as will the aquaculture production of seed for stocking by recreational fishers. Increases in food fish production may be expected in many locations, through culture-based recreational fisheries and with increasing delegation of responsibilities for the management of selected aquatic environments to anglers' associations. Recreational fisheries can in many cases bring greater economic benefits to local communities than would accrue from subsistence or commercial fishing of the same resource (FAO Fisheries Department, 1996b).

Several hatcheries are being set up or modernized to rehabilitate Caspian sturgeon stocks, as part of a major action plan being supported by all Caspian countries, including the Russian Federation, Azerbaijan, the Islamic Republic of Iran, Kazakstan and Turkmenistan (GLOBEFISH/FAO, 1997). Volga delta fish farmers have started to repopulate ponds for production of Beluga sturgeon, and Bester and Spoonbill hybrids, and a new fish processing plant is being constructed in Astrakhan for the processing of carp and sturgeon (GLOBEFISH/FAO, 1997). Prospects for culture-based fisheries on the Far East coast of the Russian Federation also appear promising; for example, the release of 800 million pink, chum and coho salmon smolts reportedly contributed 20% to the 1996 landings of 150,000 mt of salmonids sent to processing plants in Sakhalin, Primorye, Kamchatka and Magadan (GLOBEFISH/FAO, 1997). Marine ranching as well as cage culture of salmonids is seen to have good prospects for future growth in Russia (Dushkina, 1994). Efforts continue to increase production of seaweeds and scallops in the Russian Far East (GLOBEFISH/FAO,

1997) and of mussels, oysters, mullets and sturgeon in Black Sea countries (UNDP, 1996). In Estonia, a new state-owned fish rearing centre was set up in 1994 to rear salmon smolts for stocking (100,000 smolts per year) and to manage genetic material from the different salmon populations (Aps, 1996).

Regarding prospects for future aquaculture development, Muir (1995) identified several general patterns which might be expected to apply to former Eastern Bloc countries. These countries will demonstrate variable responses to political and economic changes, depending on the effectiveness of emerging management structures, the institutional strengths of the entities carrying out production, and the extent to which access to open market conditions can be gained. The transfer towards 'western' systems will be variable, and new ventures may be constrained by legal and political uncertainty and by financing risks. There may also be serious environmental problems and difficulties with quality control for export markets. Production opportunities are variable, as climatic conditions will constrain many options, but resources are significant, and could be developed to a far greater degree. There are also important areas of potential with managed water bodies, and the development of high-quality and potentially valuable recreational fisheries for European and other markets.

The FAO Fisheries Department Task Force (1995), in its assessments of supply of fish and fishery products in 2010, concluded for the region that: (i) inland capture fisheries may have a higher output through the intensification of stocking; and (ii) aquaculture production will decrease further during the coming five years after which the trend is expected to be reversed. However, given the potential markets in industrialized countries, aquaculture production in transition countries is likely to diversify into culture of higher-value species such as salmon and eels (FAO Fisheries Department, 1997).

Since the transition from centrally-planned economies to market oriented economies has created turbulence for all sectors of the economies, including the fisheries and aquaculture sector, it is suggested (FAO Fisheries Department Task Force, 1995), that there is a general need of assistance to governments in policy analysis and strategy design as they undertake to restructure and privatize the fisheries sector. The Task Force identified several possible policy interventions relevant to aquaculture and inland capture fisheries, including the need to review fisheries legislation and institutions, the requirement for upgrading of the statistical data collection systems, and in particular in the following three areas:

a) Inland fisheries and aquaculture appear to be the sources from which fish supply could increase in the future. The inland sector needs to be given attention in several respects. A general management plan for inland water resources should be elaborated covering the interactions and conflicts between the fisheries sector and other freshwater users, such as the agricultural sector. The influence--possibly increasing--on resources by recreational fisheries should be taken into account. Furthermore, the development of fish yield enhancement strategies through the development and application of new technologies would be an important aspect of managing the fishery resources for a variety of inland water bodies and ensuring sustainable production.

b) The aquaculture sector needs to be restructured. The previously state-owned enterprises are now in the transition to new ownership structures. However, part of the sector has stopped functioning because of this transition, and production is decreasing. Appropriate government intervention for the rehabilitation of the sector is necessary. This would

include provision of support infrastructure, assistance to develop business plans for potential fish farmers and investors, etc.

c) National and regional distribution systems need to be established. An important problem in marketing and distribution of fish and fishery products is the lack of infrastructure, both in the form of equipment and enterprise structures.

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3.6 Africa

North Africa, Sub - Saharan Africa

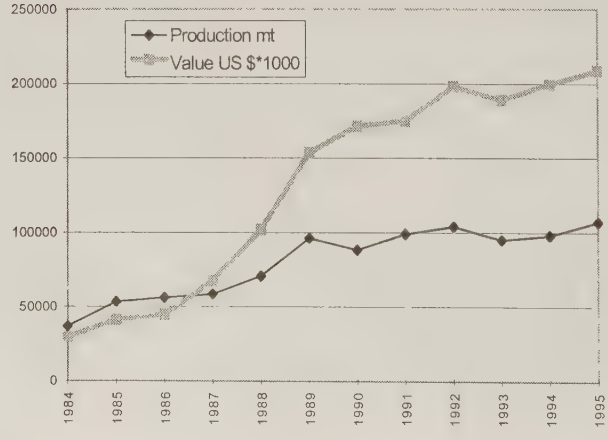
Pedini, M.

Africa's contribution to total world aquaculture production remained below 0.4% from 1984 to 1995, reaching 107,000 mt in 1995, with an increase in production of about 9,000 mt over that of 1994, and an almost three-fold increase since 1984. The value of African aquaculture production in 1995 reached US$208.7 million, increasing by over US$9.3 million from 1994 and US$179.4 million since 1984 (Figure 3.6.1).

The continent kept pace with the world average growth rate of the aquaculture sector with an APR of 12.7 in the period 1984-1995 against a world average growth of 9.6 for the same period, although from a much smaller base. This growth rate has, however, slowed down in recent years, increasing at a rate of 6.6% during 1990-1995. Compared with the capture fisheries sector, which had an average growth rate of 2.6% in 1984-1995 and 1.2% in the period 1990-1995, aquaculture has grown at a much faster pace. However, it is still a small sector when compared with the 5.4 million mt landed in 1995 by capture fisheries in the African countries.

Egypt is the most important aquaculture producer with 62,000 mt (58% of total African production), followed by Nigeria with 17,000 mt (15.5%). These major producers are followed by a group (group B, Figure 3.6.2) of nine countries led by Madagascar, with production levels ranging from 5,000 mt to 1,000 mt. The rest of the continent (group C, Figure 3.6.2) accounted for only 4.6% of the total production.

Figure 3.6.1. Africa: trends in aquaculture production and value

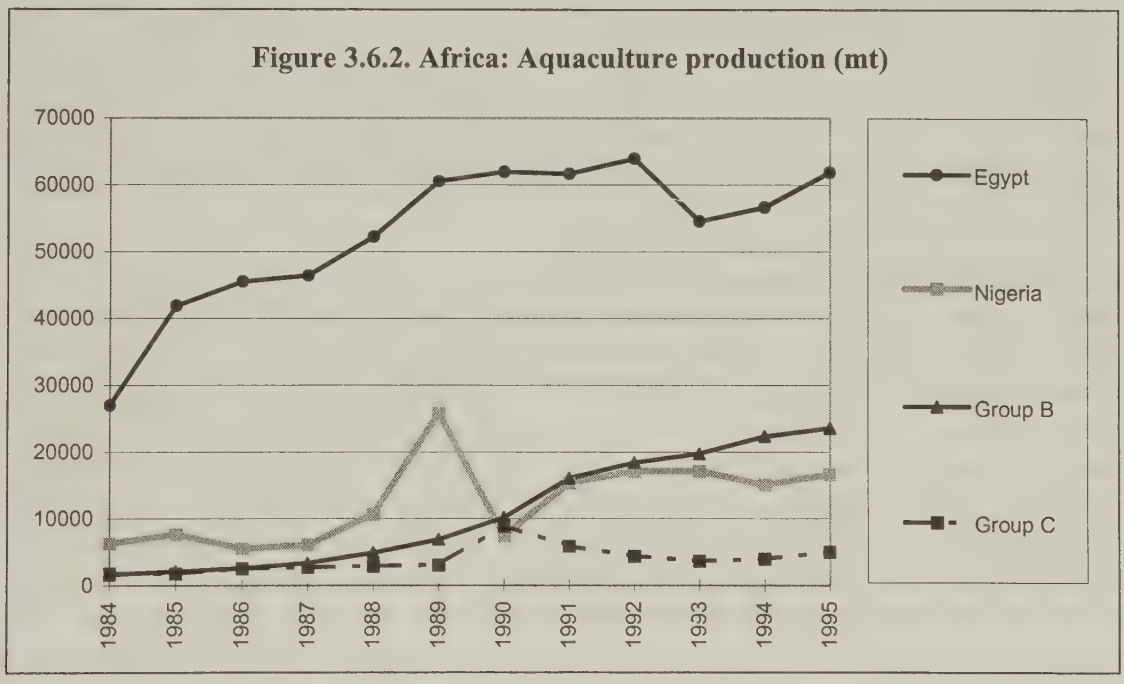


From an aquacultural point of view, the two sub-regions into which the continent has been divided in this report, North Africa and sub-Saharan Africa, differ markedly with regard to general characteristics of production, constraints and development potential, as can be noticed in the more detailed reviews of the sub-

regions which follow. Aquaculture is a traditional practice in only one country of the North Africa group-- Egypt, where extensive forms of aquaculture have been practised for a considerable period of time. In all other countries of the continent, aquaculture is a relatively new technology and has not yet acquired a clear position in national economies as a consolidated food production sector.

In terms of physical potential, resource limitations (freshwater and suitable inland sites) in the North African countries have pushed development towards the farming of marine and estuarine species, mainly for export to the European markets. The new farms tend to use more sophisticated, intensive production technologies that have been imported from other Mediterranean countries. The most likely trend which can be expected in these countries is that of progressive intensification of production, both of the traditional species and those farmed for export.

Figure 3.6.2. Africa: Aquaculture production (mt)



Aquaculture in sub-Saharan Africa has been orientated to domestic markets and practised mainly by small-scale farmers. According to recent GIS-based evaluations, the physical potential for expansion of production based on this form of aquaculture is much larger than the present levels of production. Given the physical potential, an horizontal expansion of small-scale aquaculture seems to be the most likely scenario, as a core of producers with sufficient experience emerges in the various countries. However, rural aquaculture is not the only possible form of aquaculture in the sub-region. In recent years, trials with mariculture have led to a sizeable production in South Africa and Madagascar, and the potential for replication of these successful examples appears to be there. In general, the novelty of aquaculture, combined with the economic difficulties experienced by many countries of the sub-region and the relative lack of entrepreneurs and credit for aquaculture development, presents an important obstacle to the expansion and consolidation of this new practice.

3.6.1 North Africa

Algeria, Egypt, Libyan Arab Jamahiriya, Morocco, Tunisia

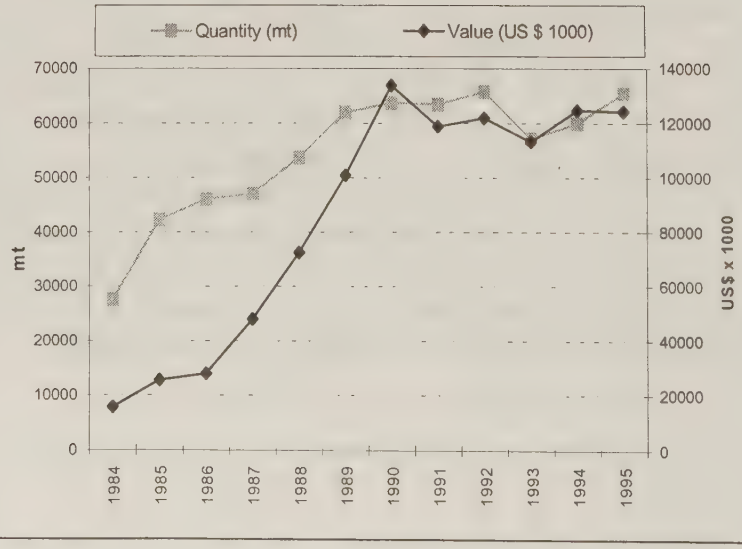
Shehadeh, Z.H.

Production and production trends

Total production from aquaculture in North African countries in 1995 amounted to 65,000 mt worth US$124 million, up 5,200 mt (9%) and US$1.6 million (1.5%) over 1994. Output from the area accounted for 61% of total aquaculture production from Africa, as in 1994. In terms of contribution to local food fish production in the area, aquaculture provided only a modest 5%, but a substantial 20% in Egypt, the main producer and most populous country.

During 1984-1995, aquaculture production increased at an APR of 8.2, compared to 5.2 for capture fisheries, from 28,000 mt to 65,000 mt, while value increased at an APR of about 21 (Figure 3.6.1.1). The sector's contribution to food fish production in the area fluctuated between 3.5% and 6.2% during the period. All five countries of the area reported production from aquaculture, but the sector is in the preliminary development stage in Algeria and Libyan Arab Jamahiriya, with production of 369 and 100 mt, respectively, in 1995. Egypt, the only country with a long historic tradition of aquaculture in the area, has always been the predominant producer. In 1995, it accounted for 94.5% of production quantity and 84.5% of value, while Morocco contributed 3.2% and 9.9%, and Tunisia 1.6 and 4.7%, respectively. Egypt is also the main producer in Africa and accounted for 57.8% of production in 1995. However, availability of resources (land and water) and inputs (seed and feed) have been limiting development of the sector in Egypt, and production levels have been static since 1992 (Figure 3.6.1.2a). Production in Morocco has been increasing consistently, at an APR of 54, since 1989, driven by increased production of Mediterranean seabass and seabream for export. Morocco replaced Tunisia as the second main producer as of 1993 (Figure 3.6.1.2b). Production in Tunisia has been largely static since 1988, due to lack of additional investments and erosion of profit margins due to sharp drops in the

Figure 3.6.1.1. Aquaculture production trends in North Africa



market prices of seabass and seabream in Europe and increases in production costs.

Finfish were the main product throughout 1984-95, contributing about 99% of quantity and value in 1995; with most production from freshwater (98%), due to the dominance of Egypt. In Morocco, however, marine finfish (seabass and seabream) contributed 55% of total

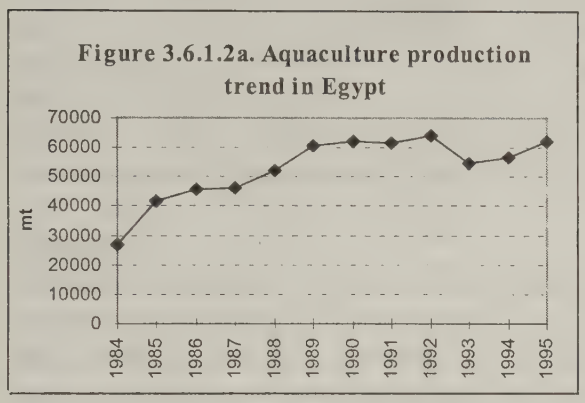


Figure 3.6.1.2a. Aquaculture production trend in Egypt

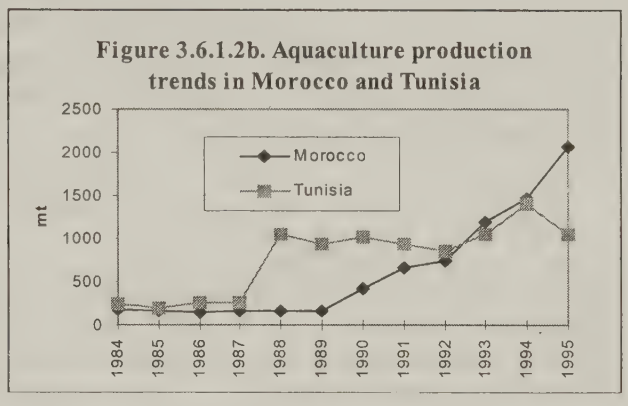


Figure 3.6.1.2b. Aquaculture production trends in Morocco and Tunisia

aquaculture production, compared to 37% from freshwater finfish (carps, trout and eels). The same is true of Tunisia, where marine and freshwater finfish contributed 54% and 34%, respectively. Accordingly, and in contrast to the situation in Egypt, aquaculture in Tunisia and Morocco is concentrated in the coastal zone. A small number of species, all finfish, accounted for 97% of total production quantity and value: common carp, Nile tilapia, mullets mainly *Mugil capito, M. ramada and M. cephalus*), catfish (*Clarias anguillaris*), Mediterranean gilthead seabream and seabass. The contribution of the main cultured species to production in 1995 is shown in Figure 3.6.1.3

In 1995, common carp, Nile tilapia and mullets were dominant in Egypt, in that order. In Morocco, the main species were seabass, seabream, silver carp and Mediterranean mussel. Although carp production in the area reached 1,200 mt (5.3%), production was still 32% below that in 1992 (Figure 3.6.1.4a). Morocco reported carp production (mostly silver and

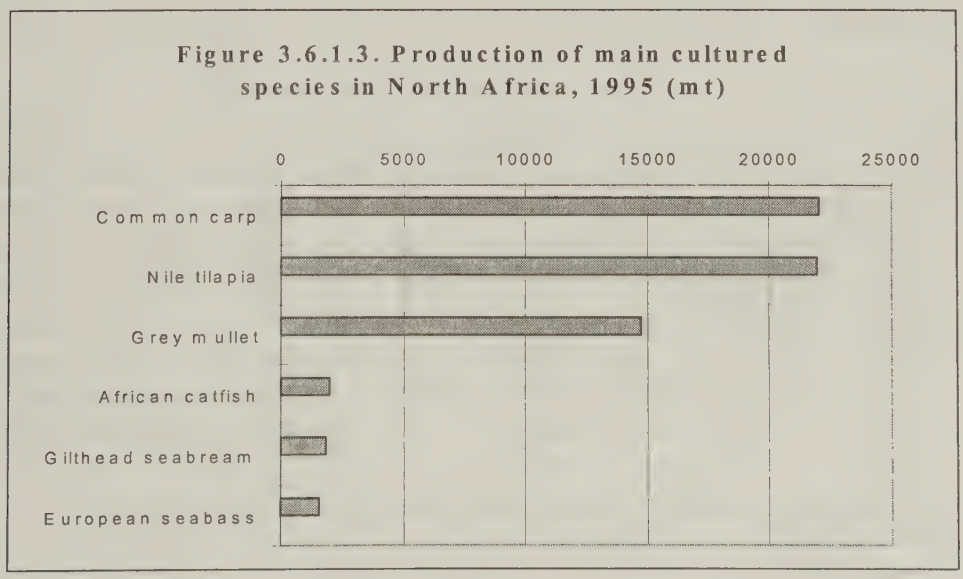


Figure 3.6.1.3. Production of main cultured species in North Africa, 1995 (mt)

grass carps) for the first time in 1995, mainly from reservoirs and irrigation canals where these fish are used for control of algae and aquatic weeds. Production of Nile tilapia in Egypt has been static and is yet to exceed 1985 levels due to shortage of seed supplies. Production

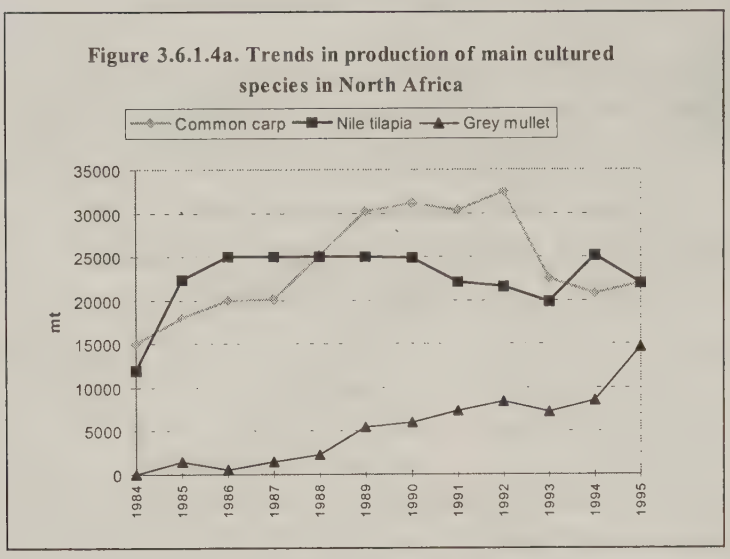


Figure 3.6.1.4a. Trends in production of main cultured species in North Africa

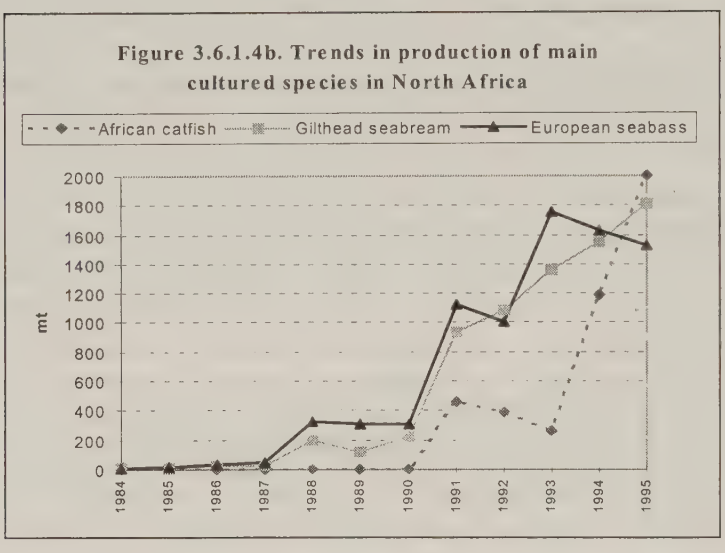


Figure 3.6.1.4b. Trends in production of main cultured species in North Africa

of mullets, which are in demand in most countries in the area, contributed 22.5% of 1995 production and has shown an APR of 23 since 1985. Increasing interest in the production of catfish (*C. anguillaris)* in Egypt is reflected in an APR of 14 since 1991 (462 mt in 1991 to 1,200 mt in 1995). Production of seabass in 1995 was down 6% (100 mt) from 1995, due to reduced production in Tunisia, while seabream production was up 29% (260 mt) due to increases in Egypt and Tunisia (460 mt) which masked a 26% (200 mt) decrease in production in Morocco (Figure 3.6.1.4b).

The products of aquaculture are marketed locally in Egypt, with the exception of bass and bream, which are exported to Europe. This is in contrast to the situation in Morocco and Tunisia, where production is mainly for export and for resident foreign communities and tourists; only about 30% of production is marketed locally.

Main issues

Development issues differ between Egypt on the one hand and Morocco and Tunisia on the other, due to differences in the history and nature of the sector, its products and its markets, that are apparent from the above analysis. In Egypt, shortage of good freshwater and land pose serious problems for the expansion of production from freshwater pond aquaculture. Most fish farms currently rely on drainage water and a large part of this slightly brackish water may no longer be available due to plans for its reuse in irrigation. In addition, aquaculture development along coastal lakes is constrained by uncertainty regarding the future use of these water bodies. The problem is largely due to the lack of co-ordinated planning for the use and management of natural resources, which recognizes aquaculture as a legitimate resource user, and the lack of familiarity with aquaculture and opportunities for its integration in farming systems, by agencies controlling these resources. There are other constraints which hinder expansion: mainly (a) the shortage of seed supplies for Nile and blue tilapias, mullets and African catfish, all of which are in demand locally, and for seabass, seabream and shrimp for export-oriented coastal aquaculture; (b) the large gap between potential and actual production from existing farms due to inadequate extension services; and (c) inadequate information for development planning.

In Morocco and Tunisia, the sector is a fairly new and modest activity, and is hindered by constraints common to new economic endeavours; e.g. consideration of aquaculture as a high-risk venture by banks, due to the lack of investment information; lack of a facilitating development framework, with enabling legislation and incentives (Tunisia has recently developed a national aquaculture plan with assistance from FAO, while Morocco is in the process of elaborating a plan, also with FAO assistance); and shortage of expertise in certain fields. However, the more immediate challenge to increasing production of currently cultured species is market-related and stems from a serious erosion of profits from export of seabass and seabream to Europe due to the significant decline in market price of these species, and the need to meet the high quality standards set by the European Union, which is adding to production costs, as well as increasing investment costs.

Outlook

There is potential for significantly increasing aquaculture production in Egypt, including a doubling of the national average production from existing farms, through sustainable intensification, and horizontal expansion into inland waters bodies and coastal areas. There is also considerable interest on the part of the private sector in aquaculture. The realization of this growth potential will depend on the resolution of both institutional and technical constraints mentioned earlier. This will involve: collaborative action among government agencies in the allocation of land and water resources and the planning of their effective multiple use, taking aquaculture into consideration; strengthening of extension services; strengthening of the information base for development planning, particularly the extent of land and water available for aquaculture, potential agriculture-aquaculture systems, potential systems and species for culture in cages and enclosures in inland water bodies, and the profitability of various production systems; and the elaboration of a national plan for aquaculture development in co-ordination with other agencies.

In Egypt, there is excellent demand in the local market for tilapia and mullets, and a growing interest in the production of catfish and Nile perch (*Lates niloticus).* Production of these species can be stimulated in the near term by resolving the shortage of seed supplies through technology transfer (tilapia and catfish), commercialization of preliminary technology for perch through pilot tests, and provision of incentives for hatchery development, including hatcheries for marine finfish and shrimp.

In Tunisia and Morocco, limitations to expansion of production of current export-oriented species will probably become more acute with time, due to lack of a comparative economic advantage over other producers in and outside Europe. Expansion of the local market for these products is unlikely due to the high production costs and market price. Diversification of high-value species in the mid term may provide temporary relief before running into the same market constraints. Tunisia is now attempting to balance an export-oriented development thrust with production of affordable fishes for the local market through controlled stocking of inland waters for licensed fishing or private lease.

3.6.2 Sub-Saharan Africa

Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Congo, Ethiopia, Gabon, Gambia, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan Swaziland, United Republic of Tanzania, Togo, Uganda, Zaire, Zambia and Zimbabwe

Pedini, M.

Production and production trends

Aquaculture statistics in many countries of this sub-region, although improving, are often not very accurate. This is probably because of the relatively low economic profile of the sector and the lack of financial resources to monitor developments and rural production. On the basis of reports from member countries to FAO, aquaculture production in sub-Saharan Africa amounted to 42,000 mt in 1995, valued at US$85.5 million (Figure 3.6.2.1). This represents an increase over 1994 of 3,600 mt and only 3,500 mt over 1992. In terms of value, the increase over 1994 totalled US$9.8 million and US$8.3 million over 1992. In 1995, Sub-Saharan Africa contributed 38.8% of the total volume of African production from aquaculture and 40.4% of the total value.

In 1995, fish and shellfish culture contributed 37,000 mt to food fish production, or less than 1% of the combined supply from capture fisheries and aquaculture. Although this contribution appears to be minimal, the percentage would be higher in the interior of many countries, where supplies from capture fisheries rarely penetrate, and represent a valuable contribution of animal protein to the diet of the rural population, as has been the case in the high plateau of Madagascar or rural areas of Zambia. The APR for production growth in sub-Saharan Africa for 1984-1995 was 14.7, with a decrease to 11.1 for 1990-1995, reflecting some growth difficulties in the latter period. Although these growth rates are better than the average world figures, it is also true that given the low initial production levels for the entire sub-region, better results should have been expected given the length of the period under examination and the number of projects which have been implemented in favour of aquaculture development. The value of aquaculture production grew at an APR of 18 in 1984-1995 and 17.5 in 1990-1995. For capture fisheries, the APRs for volume of catch in the same two periods were 2.8 and 0.8, respectively.

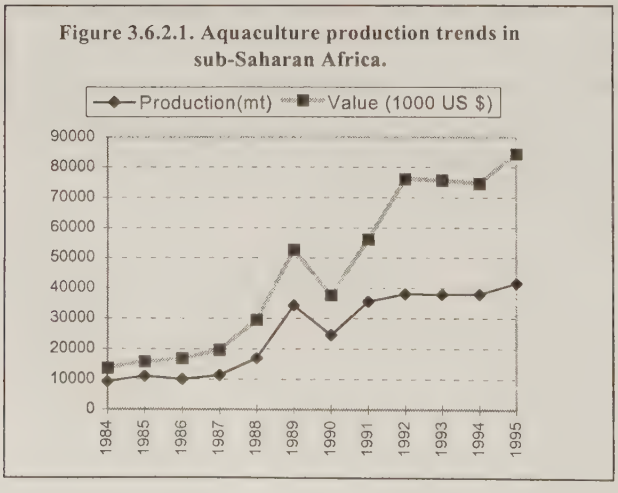


Figure 3.6.2.1. Aquaculture production trends in sub-Saharan Africa.

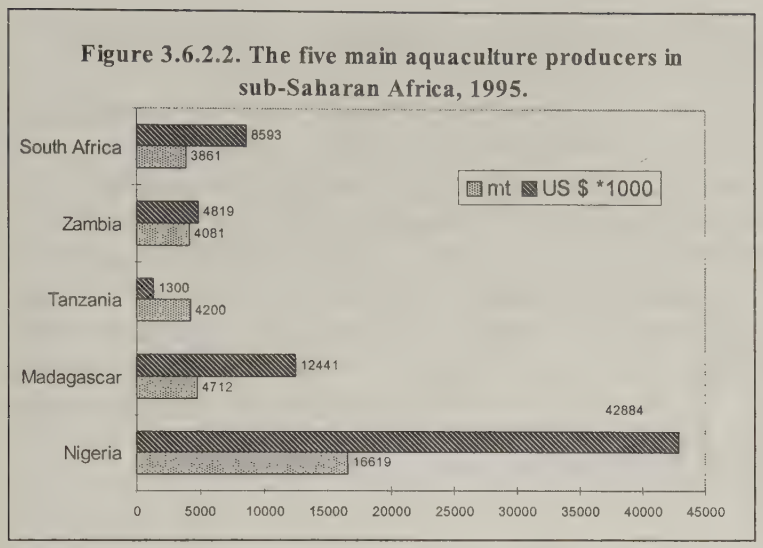


Figure 3.6.2.2. The five main aquaculture producers in sub-Saharan Africa, 1995.

Nigeria was the most important producer during 1984-1995, with an output of 17,000 mt in 1995. Several countries showed significant improvements in their production during 1984-1995, such as Madagascar, United Republic of Tanzania, Zambia and South Africa, which reached production levels ranging from 4,000 mt to 5,000 mt in 1995, from starting levels of a few hundred mt (Figure 3.6.2.2). However, most of the countries have not shown similar progress. More modest growth appears to have taken place in Togo, Kenya and Sudan, which reached production values in the order of 1,000-1,500 mt in 1995. In the group of eleven countries which produced 100 mt to 850 mt in 1995, Côte d'Ivoire and Zaire showed relatively good APRs for 1984-1995, while other countries, such as Ghana, Malawi and Zimbabwe had very minimal growth. A last group of fourteen countries had production levels between 4 and 60 mt in 1995.

Production trends were far from homogeneous in the sub-region. Aquaculture development has been negatively affected by very many factors, including climatic disasters, civil unrest, and drastic economic and institutional changes which, when linked to structural adjustment programmes, have reduced governmental support for the promotion of new technologies. In 1990-1995, 15 out of 31 countries (for which aquaculture production data series are available) showed a decrease in the growth rate of aquaculture production and, in the case of Congo and Réunion, a major decrease to levels lower that those recorded for the pre-1990 period. Other countries show a stagnation of growth; e.g. Kenya, Lesotho, Malawi, Rwanda, Sierra Leone, United Republic of Tanzania, South Africa (although with still interesting production levels), Zaire and Zimbabwe. However, on the more positive side, there are countries in which aquaculture development has maintained good growth rates, such as Madagascar, Central African Republic, Mauritius, Seychelles, Togo, Uganda, and Zambia.

In 1995, finfish were the main contributors, with a total production of 32,000 mt (76.3% of the total), followed by seaweeds (5,000 mt or 12.2%), molluscs (3,000 mt or 6.6%) and crustaceans (2,000 mt or 4.6%) (Figures 3.6.2.3 - 3.6.2.4).

Among the finfish, the tilapias were the most important species group, with production of 14,000 mt based on seven clearly identifiable species and some unspecified *Oreochromis* spp. The catfishes were the second most important group with 7,000 mt , with the African catfish, *Clarias gariepinus* (4,000 mt) and the cyprinids (4,000 mt) as the most important species, followed by salmonids (essentially rainbow trout) with 1,000 mt (Figure 3.6.2.5). Also, in terms of value, the tilapia group was the most important, at

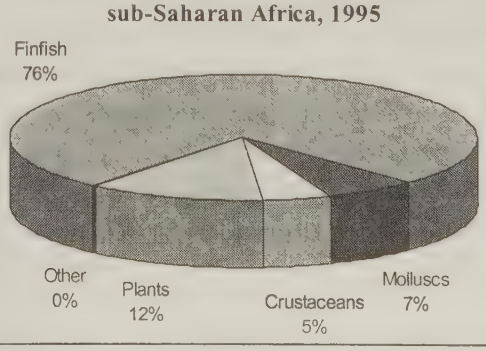
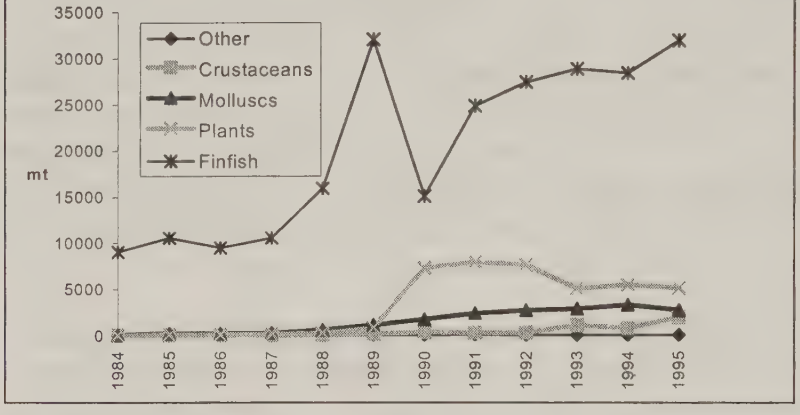


Figure 3.6.2.3. Main cultured groups, sub-Saharan Africa, 1995

US$21.8 million, followed by catfish (US$20.8 million) and salmonids (US$3.9 million).

In 1990-1995, production of tilapias grew at an APR of 11, compared with 17.5 for catfishes, with an APR of 35.5 in the case of *C. gariepinus,* showing the interest in this species especially in Nigeria, the major producer. Culture of carps also showed good growth in this period, thanks to the fast development of rice-cum-fish culture in Madagascar. The APR for common carp, *Cyprinus carpio,* in the sub-Saharan group was 43.1, even reaching 74 in Madagascar, indicating potential for considerable additional growth in the culture of this species (Figure 3.6.2.5). Rainbow trout culture experienced a slight decrease in APR in 1990-1995 after having shown an acceptable APR over the previous five years; this may be indicative of possible market saturation.

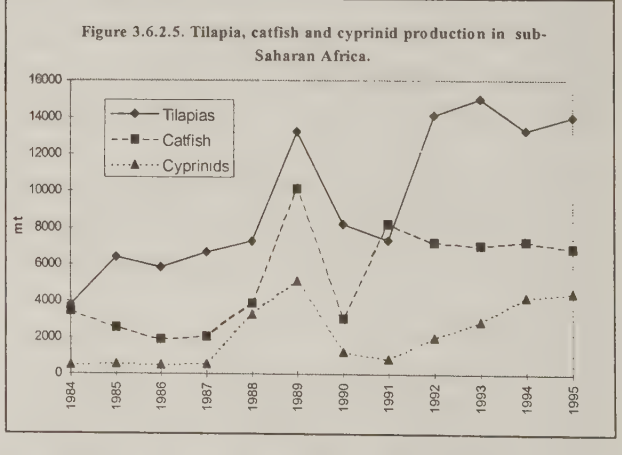
Figure 3.6.2.4. Production of main cultured groups, sub-Saharan Africa.



Only four countries reported aquatic plant production, with United Republic of Tanzania being the most important producer in 1995, followed by Namibia. Seaweeds are farmed for extraction of colloids for industrial use; the most important species in 1995 were *Eucheuma* spp., used for the extraction of carrageenans. This group developed rapidly in the 1980s reaching a maximum production of 8,000 mt in 1992 after which production decreased due to erratic output (large fluctuations) from Namibia. The value of aquatic plant production in 1995 was estimated at US$1.8 million.

Production of molluscs in 1995 was concentrated in four countries -- Mauritius, Namibia, South Africa and Sudan, with South Africa by far the largest producer (2,596 mt out of total of 2,659 mt produced). The largest contribution came from culture of the mussel *Mytilus galloprovincialis* (2,000 mt). The farming of this commodity started in the mid 1980s in South Africa and peaked at 2,700 mt in 1994. However, in spite of a very rapid initial growth (APR of 110 in 1984-1989), farming slowed down considerably in 1990-1995 and more so in the last three years, with an APR of 14 for the period. Farming of oysters showed a four-fold increase from 1985 to 1990 (from about 150 mt to 625 mt), thereafter decreasing progressively to 390 mt in 1995. In terms of value, the mollusc group was worth US$3.8 million in 1995, with mussels contributing US$2.2 million and oysters US$1.5 million.

Figure 3.6.2.5. Tilapia, catfish and cyprinid production in sub-Saharan Africa.



Crustaceans ranked fourth in terms of production volume, with a total of 2,000 mt produced in 1995. Recent development of shrimp farming was reported in six countries of this group. Madagascar is the main shrimp producer (1,500 mt in 1995), based on culture of *Penaeus monodon*, which is also farmed to a much lesser extent in Mauritius, Seychelles, South Africa and Kenya. The APR for shrimp in these countries for 1990-1995 was 131, albeit from a low production base, reflecting the interest of the private sector, particularly in Madagascar where the APR for the period was 173. Culture of freshwater prawns (*Macrobrachium rosenbergii*) was also reported in five countries--Mauritius, Malawi, Réunion, Senegal and Zimbabwe--although with modest production (less than 100 mt in the four countries). The culture of this species is most important in Mauritius, although production growth has slowed down in 1990-1995 to a rather modest APR of 4. In terms of value, crustacean culture contributed about US$12.1 million in 1995, thus ranking second in economic importance after finfish, but with a faster growth rate in 1990-1995 in terms of value (APR of 50 compared to 18.2 for finfish).

Main issues

This review of production data in sub-Saharan Africa shows that while there are a few countries in which aquaculture is becoming an important reality for rural economies, most countries have only incipient or erratic aquaculture production. Aquaculture in sub-Saharan Africa is still facing the twin problems of adoption and sustainability, and a development momentum is yet to materialize. The underlying reasons are complex, and many are not specific to aquaculture alone; they have been summarized in an earlier version of this circular (FAO, 1995) and in other publications (FAO/NORAD/UNDP, 1987; Satia, 1989; Lazard et al., 1991; Coche et al., 1994; Harrison, 1994; Brummett and Noble, 1995; FAO, 1996; Martinez-Espinosa, 1996).

Briefly, the problems encompass, inter alia, (a) poor macro-environment for development; i.e. civil unrest, weak institutional frameworks, economic problems, structural readjustments and reduced role of government before establishment of viable alternative support mechanisms, etc.; (b) limited financial resources and heavy dependence on external support for both research and development, often leading to erratic development efforts due to differences in expectations and priorities between donors and host countries, and to collapse of development efforts on conclusion of external support; (c) the novelty of aquaculture as a food-producing system and its low priority in development plans; (d) frequent droughts and poor water shortage; (e) lack of cohesive aquaculture development plans and firm commitment to its promotion; (f) rural aquaculture development strategies inconsistent with the needs and circumstances of rural communities and family economies; and (g) promotion of rural aquaculture as a stand-alone activity, with its own specialized extension service, with top-down approaches based on demonstration stations.

These problems were diagnosed and noted in the late 1980s (FAO/NORAD/UNDP, 1987) and were still valid in the early 1990s, suggesting that many governments and donors had not yet responded to the need for a change in development approach (Coche et al., 1994).

However, a paradigm shift in both research and development strategies is in progress, based on participatory planning and implementation of research and development, and on the concept of aquaculture as a component of integrated farm activities based largely on use of on-farm resources. A recent review of these approaches (Martinez-Espinosa, 1996) indicated that most were still in the exploratory stages, devising and testing new tools for more effective farmer participation and information dissemination-adoption, and exploring

opportunities for integration with various agriculture systems. As can be expected with new approaches, problems are surfacing that need to be addressed before significant progress can be made.

To begin with, the extent of the overall development effort is inadequate to the task at hand. Although integrated agriculture-aquaculture has been demonstrated to provide new benefits from existing resources under certain conditions and with proper planning (Jamu and Costa-Pierce, 1995), research efforts to identify opportunities for integration and to document their economic impact are scarce. Despite the general agreement that aquaculture should be integrated with agricultural activities, agriculture planners rarely give consideration to aquaculture as a farming activity. There is urgent need to strengthen research on integrated systems and to increase awareness of the opportunities and benefits of integrated agriculture-aquaculture systems in the agricultural sector, particularly in irrigated agriculture.

Aquaculture development efforts in sub-Saharan Africa have centred largely on subsistence rural aquaculture. Resource-poor farmers, who have been the target beneficiaries of donor-supported projects, frequently face considerable problems in effectively making use of aquaculture technology or gaining access to the resources to make it work. It has been recognized that even small-scale rural aquaculture is far more readily adopted by those with slightly more resources and entrepreneurial attitude (Lazard et al., 1991; Martinez-Espinosa, 1996). As a result, there are differences of opinion on selection of target beneficiaries in rural communities. A common trend is to work with "model" farmers to capitalize on the development potential of those with slightly more resources and entrepreneurial attitude. For many, intensification of the activity of these model farmers is increasingly seen as the key to sustained fish farming (Lazard et al., 1991; Martinez-Espinosa, 1996).

Although this should not deter efforts for the development of low-input, low-cost aquaculture systems for resource-poor farmers, it explains the slow pace of progress with this approach and underlines the need for stronger and longer-term efforts to help overcome difficulties and allow time for adoption. However, the focus on resource-poor farmers need not deter aquaculture development efforts based on mobilization of the more entrepreneurial groups, particularly in peri-urban areas, to supply city markets and major local markets, especially if this is not done at the expense of rural communities. Interestingly, in recent years, more progress in aquaculture has been made in those countries where entrepreneurs and progressive farmers have been systematically involved (e.g. in Madagascar, Kenya and Zambia).

Another issue is the supporting infrastructure required for rural aquaculture development. Much work lies ahead to tackle problems of incorporating participatory planning approaches at the field level with the more traditional "top-down" modes of planning commonly used in governments and development institutions. Means of linking participatory planning in the field with mechanisms for policy formulation and national planning are felt to be generally lacking (Martinez-Espinosa, 1996). Efforts are also needed to merge aquaculture extension with that of agriculture.

Outlook

The contribution of aquaculture to fish supplies (only 0.7%) and food security, based on available statistics, is still modest although considerable potential exists in terms of land and water across the sub-region in relation to the present production levels. It is estimated that less than 5% of this potential has been used (Kapetsky, 1994). At present only six countries

account for 84% of total production (42,000 mt) in the sub-region. However, the development of the existing potential appears to be distant due to a complex of factors also linked to the general development pattern of the sub-region, not totally specific to aquaculture.

An evaluation of the APRs for the period 1990-1995, for species and countries, suggests that rapid growth of production is likely to continue for the farming of *P. monodon* and common carp in Madagascar (APRs of 173 and 73, respectively), and current (1995) levels of production which can be considered commercial in both cases. Other species which show good growth potential are *C. gariepinus* in Mali, and *Tilapia rendalli, Oreochromis macrochir* and *O. andersonii* in Zambia. More moderate growth potential can be expected for the farming of *O. niloticus* in Mali, Sudan, Senegal, and Central African Republic, and for *C. gariepinus* in Nigeria.

There seem to be still untapped possibilities for integration of aquaculture in small water bodies and irrigation schemes, and in some cases for integration with rice culture. Also a broader approach to aquaculture development, in terms of target groups involving small-scale and commercial-scale entrepreneurs in addition to rural development efforts, would help mobilize resources of the private sector with the aim of supplying urban centres with fresh fish, and for production of export commodities where opportunities exist.

The use of small reservoirs for extensive forms of aquaculture in some of these countries represents a new option for development not yet properly exploited, although some studies have been carried out and development projects have been implemented in Burkina Faso for example (Traore and Baijot, 1989). Another option to overcome the scarcity of water for aquaculture in the more arid countries is the integration of aquaculture in irrigation schemes which has been tested in Mali with encouraging results (Coche and Muller-Fall, 1993; FAO, 1993). However, in spite of the untapped potential, the expansion of aquaculture in these countries may be limited by low consumption of fishery products. Consumption is very low in the Sahelian countries, with values in the order of 0.4 kg/caput/year (average values for the period 1991-93) in Niger and 1.4 kg/caput/year in Burkina Faso.

Expected difficulties in ensuring adequate fish supplies in the medium term should favour aquaculture development in some countries, as prices of fish will increase. However, this trend may be reversed in some of the southern African countries by the increased supply and improved distribution of cheap frozen pelagic fish. The current international concern and focus on food security in the region may lead to a renewed thrust to develop certain forms of aquaculture in the sub-region. However, a substantial research effort will be needed at the field level to adapt aquaculture development approaches to diverse rural environments and farming systems in which it is supposed to be integrated. Major and co-ordinated support from donors will be required to establish sounder bases for such development over the next 15 years. In order to increase fish production, governments in the sub-region are likely to emphasise the strengthening of capacities to manage capture fisheries on a sustainable basis, and the elaboration of more appropriate frameworks for the development of aquaculture.

Achievement of sustainable increases in aquaculture production requires that emphasis be given to: (a) integration of fish culture with agriculture using family level technologies applied in schemes that involve water storage practices, including micro-irrigation and small ponds; encouraging aquaculture in irrigation networks and integrated rice-cum-fish culture, and in farming systems in general as appropriate; (b) encouraging investment-oriented aquaculture by progressive farmers and entrepreneurs in peri-urban areas; and (c)

aquaculture-based stocking and stock enhancement in small and medium-size water bodies, focusing on reservoirs and eventually on medium-size lakes and river floodplains, using local species and including the development of cage culture.

External assistance continues to be essential for further development, but it should be more carefully planned and designed with longer time frames in order to establish strong bases for sustained development. It should also be provided mainly where there is evidence of strong government commitment to the sector and reasonable prospects for success.

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3.7 Oceania

Australia, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, Micronesia, New Caledonia, New Zealand, Papua New Guinea, Samoa, Solomon Islands.

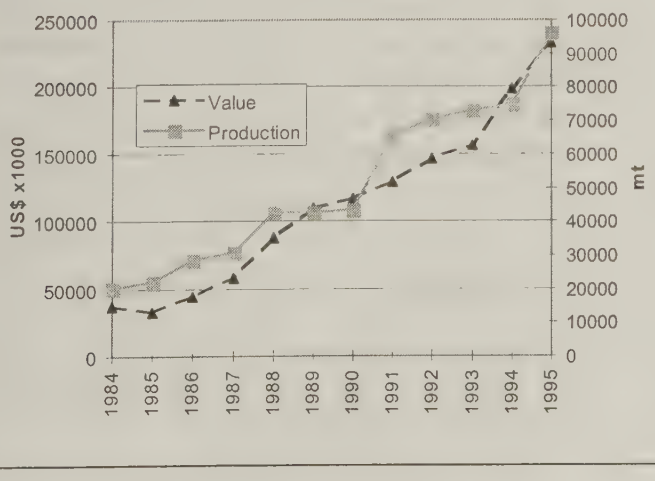
Pedini, M.

Production and production trends

Total reported production from aquaculture in this region in 1995 amounted to 96,000 mt worth US$230.2 million, with an increase of 22,000 mt (28.8%) and US$35.7 million (18.4%) over 1994 (Figure 3.7.1). In the global context, these figures represent 0.3% of the total volume and 0.6% of the total value. In terms of contribution to local fisheries products in 1995, aquaculture supplied 9.3% of the combined output from capture fisheries and aquaculture.

During 1984-1995, aquaculture production increased at an APR of 15.2, compared to 5.6 for capture fisheries, which in this region have witnessed a considerable expansion in production. Despite the importance of capture fisheries for Oceania in view of the extensive EEZs of the member countries, aquaculture has been tested in 12 countries of the region and has established itself as a profitable parallel form of supply of fishery products in some of them. The growth and progressive consolidation of aquaculture in Oceania has been driven by New Zealand and Australia. The former produced 68,000 mt in 1995 (with an APR of 18.1 for 1984-1995), while Australia contributed 25,000 mt with an APR of 10 in the same period (Figure 3.7.2). The combined output from both countries accounted for 97% of the total volume of aquaculture production in Oceania.

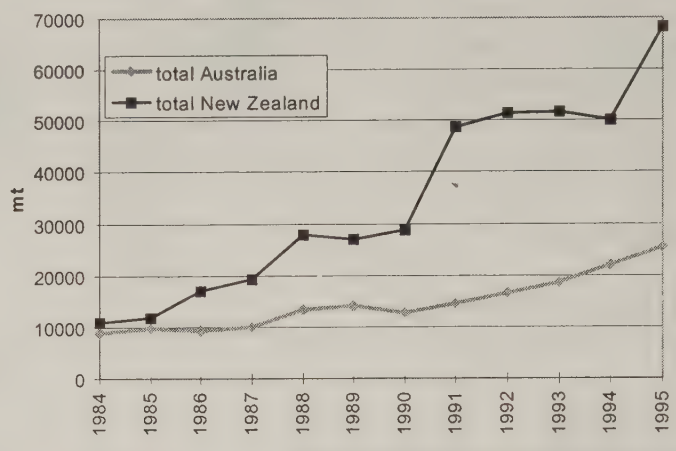
Figure 3.7.1. Oceania: aquaculture production trends



The historical pattern of aquaculture production in these two countries is rather different. Australia has experimented with, and apparently also abandoned, more species than New Zealand. From the records provided to FAO, some 31 different species have been cultured, of which 11 were abandoned. In the mid 1980s, there was a gradual consolidation of the sector around six high-value species which accounted for 90% of the production in 1995. From 1992 to 1995, Australian aquaculture production grew rapidly (albeit from a low initial production base), increasing

by about 9,000 mt (or 50%). New Zealand has shown a more steady growth, based on only five species, with an increase of 32.8% in total volume from 1992 to 1995, also an indication of the healthy state of the sector.

Figure 3.7.2. Aquaculture production in New Zealand and Australia

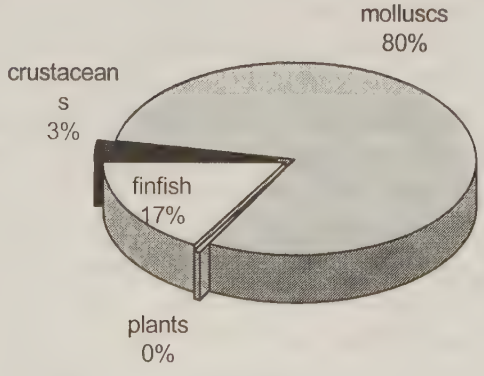


In the smaller islands of the region, aquaculture is seen as a provider of food and/or income, depending on the country. Export-oriented aquaculture is dominant in the Cook Islands and French Polynesia (pearl culture), in Kiribati (*Eucheuma* production), and to some extent in New Caledonia (shrimp). In Fiji and Guam, production of food for local consumption is the main developmental objective of aquaculture.

Molluscs were the main regional aquaculture group in 1995 on the basis of volume (77,000 mt, or about 80% of total production), with mussels from New Zealand (63,000 mt, or 82% of molluscs) dominating the scene (Figures 3.7.3 and 3.7.4). Edible oysters contributed 12,000 mt with *Crassostrea gigas* from Australia, New Zealand and New Caledonia contributing 7,000 mt of the total, and with production growing rapidly from an initial production base of less than 2,000 mt in 1984. *C. commercialis* from Australia contributed 5,000 mt in 1995 but has shown a slight decreasing trend over the 1984-1995 period.

Finfish production accounted for 16,000 mt, or about 17% of total regional production volume from aquaculture in 1995, with an APR of 27 during 1984-95. Salmon (9,000 mt) and trout (4,000 mt) from Australia and New Zealand dominated production, accounting for 83% of finfish production. Tuna farming is a recent (1992) development in Australia and is growing rapidly. Production in 1995 was about 2,000 mt.

Figure 3. 7.3. Oceania: production of main cultured groups, 1995



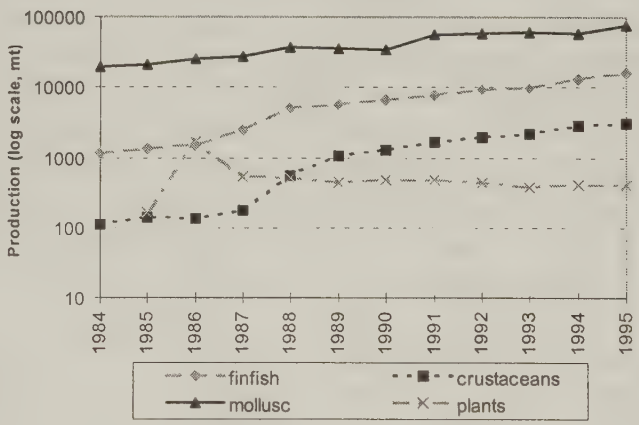
Crustacean farming contributed 3,000 mt in 1995 with penaeid shrimp as the main group (2,600 mt). Of this group *Penaeus monodon*, cultured mainly in Australia, is the main species (1,600 mt), followed by *P. stylirostris* (900 mt), cultured in New Caledonia. The interest in freshwater prawns and lobsters in the region is noteworthy. Three species of the genus *Cherax* are reported to be farmed in Australia and Samoa (336 mt), and *Macrobrachium rosenbergii* has been tested in five islands, although it is only farmed in Fiji and French Polynesia at present.

Seaweed culture, mainly *Eucheuma* spp., supplied 400 mt of product in 1995, largely from Kiribati and Fiji.

Main issues

Taking into account the differences in domestic markets, land mass and proximity to other export markets, the countries of Oceania fall into two groups with respect to major issues: Australia and New Zealand on the one hand, and the rest of the islands on the other. In the two major producers, an important issue for expansion of aquaculture production concerns the need to ensure sustainable development with due attention to conservation of the environment, particularly in the coastal zone. Due to the novelty of aquaculture development in both countries, the combined efforts of the public and private sector are necessary to develop well co-ordinated national plans and regulations for sustainable development.

Figure 3.7.4. Oceania: production of main cultured groups



With regard to physical issues, the incidence of natural calamities (cyclones) is very high in some of the smaller islands, representing a menace for aquaculture facilities. Several farms have already been destroyed and even the stock enhancement programmes for coral reefs may suffer considerably from the devastation caused by tropical storms. Bio-technical issues range from problems encountered in Australia with toxic algal blooms, which affect oyster and mussel farms, to the limited marketability of some of the species farmed or being considered for aquaculture due to restrictions imposed by the CITES agreement. In addition, production packages for local species are not thoroughly developed, and regional collaboration for technology development is scarce. This fact, linked to the complexity of the development of packages for a new species and to the limited resources available in many of the smaller islands, has pushed producers to favour the use of exotic species, which may have negative environmental and biodiversity impact.

On the economic side, with the exception of the larger states and territories, it is difficult to reach an economy of scale for production, due to the relatively small size of many local markets, and to the difficulty of marketing abroad due to remoteness of the markets and the limited possibilities for transport of perishable products over long distances. Also related to economics is an important institutional issue: the region, again with the exception of the larger states, possesses very limited institutional and financial capability to promote development through the public sector. Thus, research and development efforts depend to a large extent on external aid (see Section 2.8 *External Assistance*). The limited allocation of resources to aquaculture development is also due to competition for these resources with the marine fisheries sector, which is a very important source of foreign currency, and is therefore the focus of attention of the public sector and regional institutions. This has resulted in a scarcity of properly trained personnel with hands-on experience in aquaculture research and development. External aid has been used in the region for a vast number of projects, most of which were not properly focused and have failed, thus generating serious doubt about the

economic viability of aquaculture. Regional initiatives that could have contributed to the creation of networks, permitting a pooling of resources and a more efficient transfer of expertise from the more advanced countries, have been scarce and largely underfunded. Similarly, co-operation among the states and territories in the region has been poor.

Outlook

The potential for growth appears to be significant and is centred in Australia and New Zealand, where the average annual growth rates in 1984-1995 have been 10% and 18%, respectively. Growth of the sector has accelerated in Australia to 14% per year and has continued at a very healthy 19% per year in New Zealand. Areas for expansion of farms are certainly available and the governments are in the process of regulating development to favour sustainable expansion of production.

In the smaller islands, the best prospects seem to be for export commodities (high-value non-perishable products like pearls) aimed at specialized markets. However, the potential for pearl culture will be rather tightly controlled by the private sector, especially Japanese buyers and companies, to maintain prices. Hatchery techniques for pearl oyster breeding are not easily transferred because of this tight control, and the smaller islands are basing their production on the availability of natural stocks. Therefore, additional growth of pearl culture in the South Pacific in the medium term will probably occur in only a few places and under tight market control. For other local species that have potential in Asian markets (e.g. sea cucumbers, giant clams, etc.), technologies for commercial production have still to be perfected, and institutional capacity for technology development is very scarce in the South Pacific. Freshwater aquaculture for local markets may have potential in the larger islands.

Examination of the growth rates of the various commodities shows clearly the novelty of aquaculture in the region. There was very low initial production in the mid 1980s, which accounts for the high average growth rates over the period 1984-1995. By comparing the APR values for the various commodities for 1984-89 with those of 1990-1995, it should be possible to verify the changes and, bearing in mind the levels of production, to derive an idea of possible trends.

In terms of species groups, the analysis of growth rates in these two periods indicates that finfish culture growth has slowed down in the 1990-1995 period from an APR of 37.8 to an average 19, which is still a very interesting value. In the case of finfish, the groups which appear to have better prospects are: the salmonids, for which production is still growing at rates in the order of 16% (1990-1995) in spite of the fact that annual production is already sizeable at 13,000 mt; and tuna, a very recent entry, production of which in Australia has been growing annually in the last four years at 79% (1990-1995), reaching over 1,900 mt in 1995. As the form of farming practised for tunas is mainly fattening of wild-caught specimens, a limit for the expansion of this highly lucrative form of aquaculture in the medium term would be the availability of stocking material. Prospects for growth in the production of seabass (*Lates* spp.) and tilapias, based on analysis of the APRs, appear to be more modest than for the previously mentioned groups. Although still at annual production levels in the order of 2-300 mt (1995), their annual growth rates during 1990-1995 (51% and 9%, respectively) auger continued growth.

The average annual growth rate of crustacean aquaculture has slowed down from 56.7% to about 19%, which is still substantial taking into account the present level of production of over 3,000 mt in 1995. Possibilities for expansion of shrimp culture in the near future

certainly exist, in particular in Australia and to a lesser extent in New Caledonia. Production is already about 2,600 mt, which indicates that the pilot-scale period has passed. *Cherax* spp. culture is a novelty in this field and starting to become significant, with annual growth rates of 25%, although production is still in the pilot stage.

Mollusc culture growth rate has increased from 13.2% (1984-1989) to 17% (1990-1995), pushed by the rapid development of New Zealand mussel production, which maintained a very fast 20% growth rate for the period 1990-1995. With ample areas for culture and well established distribution channels, it could be expected that mussel culture will increase its dominance in the mollusc group in the years to come. Other mollusc species seem to have a rather limited potential for growth in the near and mid term. Oyster production has slightly increased in growth rate from around 2.5% in 1984-1989 to 5.4% in 1990-95, while pearl oyster production growth has slowed from 10.5% to 4.7%, indicating the control by the recipient markets on increase of production. Seaweed farming trends do not indicate a bright future in Oceania for these commodities, possibly due to the remoteness of the area and the availability of alternative sources of supply.

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